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# THE PRACTICE OF SANITATION

BY

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# FOREWORD

During the past ten years the world has changed ideologically and socially perhaps more profoundly than in any previous decade. One thing has remained unchanged, however,—the will to live is stronger everywhere in the world than it has ever been.

In the United States of North America that will to live has been eminently successful. The expectancy of life at birth is now rapidly approaching 70 years. Never before has any vast population in the world demonstrated that life expectancy could be more than doubled by conscious effort toward the best uses of human and material resources.

No inconsiderable part of these efforts have been exercised in the field of environmental sanitation. The fruits of these efforts are everywhere manifest in our country by the reductions or the virtual elimination of insect, sewage or rodent borne diseases, such as malaria, typhoid, typhus, and the dysenteries. Measures for the protection of drinking water, for the disposal of sewage, for the safeguard of food, etc., have paid enormous dividends in the saving of human lives and in the even greater saving of dollars.

Yet for well over three quarters of the population of the world these beneficent results are still largely to be attained. Neither personnel, funds nor understanding are available in sufficient amounts to bring even a tithe of the benefits we have been fortunate enough to gain.

Even the layman, who stops to think, may wonder what the mechanisms of sanitation are, from which some of these blessings flow. He and the technologist who serves him require an easy reference to these techniques.

This easy reference, the authors of the present volume hope to provide. One can but admire the courage and the diligence of an author who assumes such a task of wide coverage and complexity. That he succeeds is a tribute to his energy and patience. That he pays a necessary penalty in failing to provide detailed information on every feature of environmental sanitation was to be expected. To accomplish this would require a library of textbooks.

The volume should find a wider field of reader in the teacher, the general student, the nurse, the health officer, and the layman than would be the case if it were crammed with the technology of the art of keeping the physical environment safe.

November 1, 1950

ABEL WOLMAN

# PREFACE

This text has been developed as a guide in environmental sanitation procedures for the training of physicians, nurses, sanitarians and students in sanitary engineering for a career in public health. It seeks to bring together in one volume the pertinent facts comprising sanitation practice as it is today in this country.

We appreciate the Foreword by Dr. Abel Wolman, Professor of Sanitary Engineering, Johns Hopkins University.

We also acknowledge with pleasure the assistance given by Ann K. Magnussen, Administrator, Nursing Service, American Red Cross; Col. William A. Hardenbergh, USAR, Editor and President of Public Works; Dr. Wilmer H. Schulze, Director, Sanitation Section, Baltimore City Health Department; Mr. George L. Hall, Chief Engineer, Maryland State Department of Health, Mr. Harold B. Robinson, Senior Scientist, Region II, United States Public Health Service, and Mr. Ferdinand A. Korff, Director, Food Control Bureau, Baltimore City Department of Health. Their criticism has increased materially the value of the text.

Illustrations of technical equipment made available by various manufacturers and permission for reprinting certain other photographs and factual data are gratefully acknowledged.

THE AUTHORS

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## Chapter I

# FUNDAMENTAL CONCEPTS

Sanitation may be defined as the control of those factors of the environment affecting public health, so that disease is prevented and positive health is gained. It is apparent therefore that the fundamental precepts will be found in the sciences of bacteriology, biology, entomology, epidemiology, chemistry, and physics. Without engineering application of the basic principles of these sciences to the design of machinery and structures, modern urban and rural life and present day civilization would have been impossible. It is obvious therefore that the history of sanitation is the record of the development and subsequent application by engineering principles of these sciences to public health use.

Initial sanitary effort was to secure safe water supplies and satisfactory methods for sewage disposal. Hippocrates, about 400 B.C., advocated boiling and filtering of a polluted water before drinking. Many of the early Mosaic laws referring to dietary regulations and treatment of diseased persons had their origin in sound facts of hygiene. Pliny, 70 A.D., in his "Natural History" discusses the characteristics of potable waters.[10] The modern practice of sanitation probably originated in England in 1843 with the appointment of a Royal Commission on the Health of Towns.[8]

The observations and descriptions of bacteria published in 1675 by van Leeuwenhoek may be considered as the origin of bacteriology as a science.[5] Plenciz in 1762 discussed the etiological connection between bacteria and disease and was the first to postulate that some diseases were caused by specific micro-organisms.[13] Cagniard de Latour and van Schwann demonstrated in 1837 that the oval bodies observed in yeast by van Leeuwenhoek were actually minute living vegetable cells, associated with fermentation.

The fundamental discoveries of Pasteur[6] established bacteriology as a science. His work in 1856 showing that alcoholic fermentation was possible only in the presence of yeast confirmed the observations of Latour and van Schwann. He later proved that specific organisms produced characteristic ferments. This led to the study of wine fermentation in 1863 with the elimination of undesirable ferments by heating below the boiling point. Eradication of pebrine, a bacterial disease, from the French silk worm industry followed in 1865. The discovery in 1876 by Koch that bacteria were present in the blood of cattle suffering from anthrax was followed in 1877 by Pasteur's conclusive demonstration that these organisms actually caused the infection. This work established beyond question the germ theory of disease.

Hoffman in 1869 was the first to stain bacteria. Koch in 1877 developed Weigert's method of staining, making possible extensive studies of bac-

FIG. 1. William Henry Welch. Director 1918–26, School of Hygiene and Public Health, Johns Hopkins University. (This was the first school organized as a separate institution to provide professional training in public health.) Courtesy, Welch Medical Library.

terial forms. The discovery by Gram, in 1884, of the staining procedure now commonly used, introduced a precise technique into these studies. In 1881 the introduction of solid media for the isolation of pure cultures by Koch laid the foundation of modern bacteriology.

The introduction of aseptic surgery by Lister[9] may be considered the initial application of bacterial principles to medicine. It is of interest to note that he conceived the idea of wound sterilization from observing the abatement of odors from impounded sewage by treatment with creosote.

Eberth identified the typhoid bacillus in 1880 and Escherich in 1885 isolated the colon bacillus from feces. He later demonstrated that the colon bacillus organism normally inhabited the intestinal tract of man and animals. Since this group of related organisms (Coliform group) is present in the discharges from all animals and is therefore found in sewage, tests for the safety of a water supply are based upon the presence or absence of these species. Without the development of the science of bacteriology the sanitarian would have been hopelessly lost in the search for control procedures.

Epidemiology also has played its part in the development of sanitation practices. The historic work in 1854 of Snow and York in investigating the now famous London Broad Street well epidemic proved the inter-relationship of sewage, drinking water, and cholera. The Hamburg-Altona epidemic[12] in 1892 not only demonstrated again the sewage—drinking water—cholera chain, but also showed the effectiveness of sand filters in removing pathogenic organisms from water. The typhoid fever outbreaks in Salem, Ohio (1920); Lansing, Michigan (1919); and Greenville, Illinois (1925) unfolded the story of typhoid fever contracted from water. The spread of amoebic dysentery by means of drinking water polluted through faulty plumbing was observed in Chicago in 1933.

Still another science, entomology, is of importance to public health and the sanitarian. Some of the writings of Hippocrates probably refer to quartan malaria,[14] but it was not until 1880 that Laveran identified the malaria parasite. The subsequent investigations of Sternberg, Ross, Grassi, and Manson are associated with our present knowledge of the man—mosquito—man route of malaria. In 1893 Smith and Kilborne demonstrated the tick transmission of Texas cattle fever.

Yellow fever is also an example of the way entomology has placed tools in the hands of public health workers. Although yellow fever epidemics had raged in various parts of the world for centuries, it was not until 1881 that Finlay advanced the true explanation of the etiology of this disease. Reed[11] and his group in 1900 proved this theory, thereby opening the way for effective control. Sanitation has been developed too by the application of the many discoveries of chemistry. These newer principles

made possible processes for the purification of water, sewage and trade wastes that seemed impractical a few years ago.

Apart from dependence upon general chemistry for basic analytical reactions the advancement of sanitation has been directly affected by the development of colloidal chemistry. Modern colloidal chemistry began with the work of Graham in 1861, although experiments to differentiate between crystalloids and colloids had been reported as early as 1844 by Selmi.[2] From this has come the development of gel formation, emulsions, coagulation, surface adsorption and other fundamental principles of colloidal chemistry. In water treatment chemical coagulation with alum followed by filtration through sand filters was patented by J. W. Hyatt and Albert R. Leeds in 1884.[7] This was the first application of the principle of coagulation with an electrolyte to remove turbidity from water on a plant basis.

Sørenson in 1909 conceived the pH scale for measurement of hydrogen ion concentration and also investigated various indicators for making this test, publishing a selected list of those suitable.[3] The classic work of Clark and Lubs in 1917[4] provided an excellent series of indicators and standards for precise pH determinations. This made possible a practical method for accurate determination of hydrogen ion concentration without complicated apparatus and procedures.

The principles of surface adsorption have been extensively utilized since 1874 for the removal of manganese and iron from water supplies in conjunction with an aeration process.

The activated sludge process for sewage treatment reached outstanding development in the work of Arden and Lockett in 1914.[1] This procedure is now of equal importance to the conventional sedimentation-trickling filter installations.

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Chapter II

# PRINCIPLES OF DISINFECTION

Although Patterson[8] some years ago clarified the nomenclature used for the destruction of bacteria considerable confusion still exists in the precise use of these terms. This is understandable when it is recognized there is some difference between the scientific meaning and that assigned by popular usage.

Sterilization signifies the destruction of all living organisms. A sterilizing agent destroys all forms of life. Steam under pressure and fire are the most commonly used agents.

Germicides will kill micro-organisms exclusive of spores. They are usually chemical compounds but ultraviolet radiation and oligodynamic silver are also germicides. The term bactericide is synonymous with germicide except that its usage is restricted to the destruction of bacteria rather than any micro-organism.

Disinfection denotes the destruction of infectious organisms by a germicide.

Bacteria are inhibited in growth and held in a state of suspended metabolism, or condition of bacteriostasis by a bacteriostat. Such an agent is bacteriostatic.

Sanitizing is a term that has come into use recently among public health people. Its basic meaning is "to render sanitary". It implies rendering an article clean of any esthetically objectionable material plus elimination of any harmful contamination. It indicates cleansing and bactericidal treatment.

An antiseptic may be either germicidal or bacteriostatic. If used for immediate destruction of bacteria as in gargles, douches, etc., it is bactericidal. When used to dress surgical wounds, with dependence upon a long contact period to inhibit bacterial growth, it is bacteriostatic. Its primary function is to prevent bacterial multiplication.

The control of pathogens in water supplies, food production, milk control, etc. is commonly called sterilization. This is a misnomer since many types of organisms remain after treatment. Disinfection is the proper term. This term is not popular because of its close association with foul smelling chemicals and the average person resents its use in connection with food and drink. A similar situation exists in the sanitation of eating utensils commonly referred to as "sterilization". Actually eating utensils are seldom rendered sterile but by the use of "sterilizing agents" and bac-

teriostats the organisms are reduced in number below that considered to be of public health significance.

## DISINFECTION MECHANISM

There are several reactions that cause the death of bacteria, namely, oxidation, hydrolysis, coagulation of cell proteins, destruction of essential enzymes and formation of salts within the cell. Several reactions may be produced by a given germicide. Heat causes the destruction of essential enzymes as well as the coagulation and dessication of cell proteins. A bacteriostatic reaction is considered a surface reaction in contrast to the deep-seated action of a bactericide.

The absence of reproduction of bacteria is used as a measure of determining the efficiency of disinfectants and of sterilization. The failure of subcultures to grow within their normal incubation period, after inoculation into a suitable medium, is accepted as evidence of bactericidal action. It is recognized that bacteriostasis may invalidate these tests giving a false death point. Careful technique is required to assure death[7] so that cultures are not discarded too early.

Organic material surrounding a cell will absorb and neutralize a bactericide reducing the concentration reaching the protoplasm to such an extent that the germicide may no longer be potent. Even with heat sterilization efficiency may be decreased by the protective action of colloids which may retard hydrolysis and dessication of the cells.

## GERMICIDAL AGENTS

Of the many substances possessing germicidal properties only chlorine, bromine, ozone, quaternary ammonium compounds, oligodynamic silver, cresols, certain acids for food preservation, alkalies used as detergents and the physical processes of heat and ultraviolet radiation are of practical value in sanitation control.

The factor of cost and convenience of operation together with absolute dependability when applied under the desired conditions will determine the selection of a germicide. Ozone and ultraviolet radiation are efficient bactericides when used under favorable conditions but the complicated control procedures and cost of application prohibit their general use. Cresols are satisfactory disinfectants where food and drink are not involved and where their odor is not deleterious. In many instances these compounds are used so that their odor will be an indication that disinfection has been practiced.

Dry heat or steam under pressure is the preferred method for the sterilization of small objects not adversely affected by heat. Chlorine,

either as a gas or soluble hypochlorite, because of its low cost, ease of application, and reliability, is the germicide of choice in many instances.

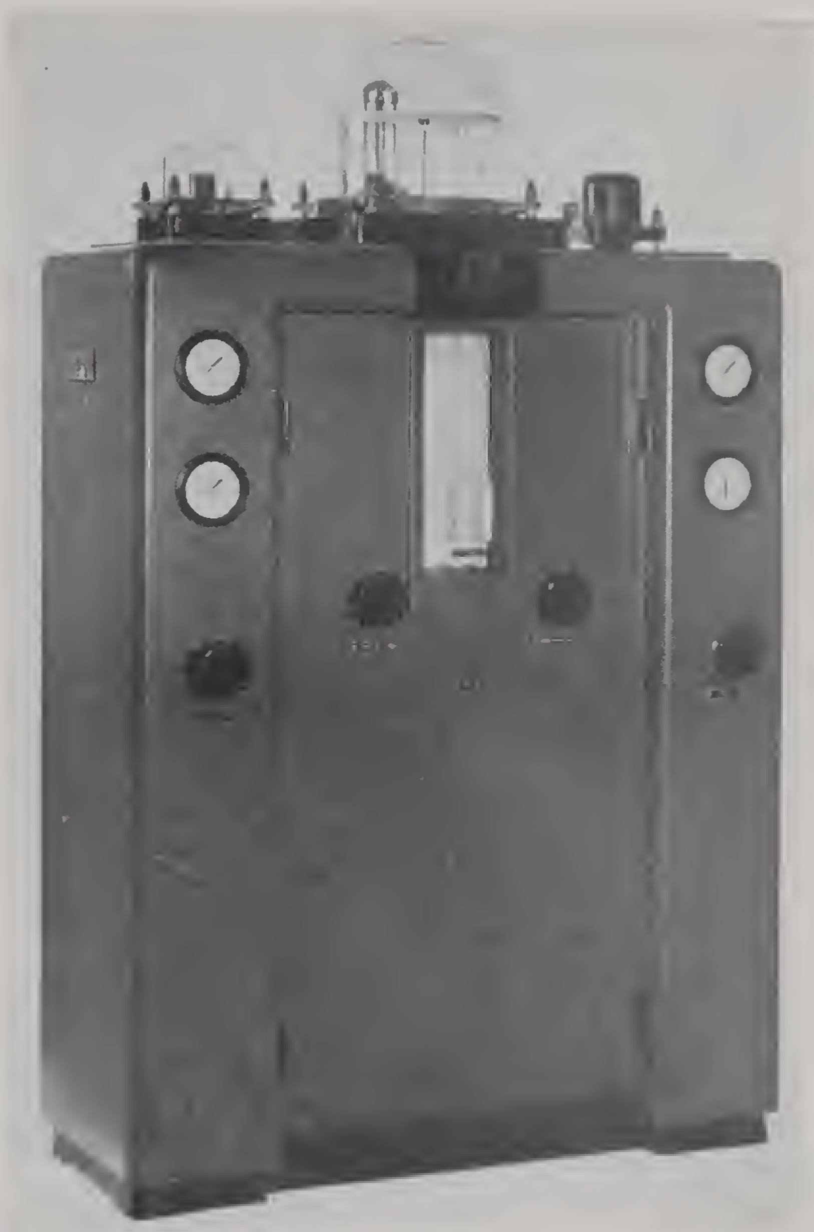

FIG. 2. Large capacity air operated visible vacuum chlorinator. (Courtesy, Wallace and Tiernan Co.)

## CHLORINE

Chlorine reacts with water forming hydrochloric and hypochlorous acids. The hypochlorous acid in dilute solution dissociates into hydrogen and hypochlorite ions:

$$Cl_2 + H_2O \rightarrow HCl + HOCl$$
$$HOCl \rightarrow H + OCl$$

A chlorine solution therefore may contain molecular chlorine ($Cl_2$), hypochlorous acid (HOCl) and the hypochlorite ion ($ClO^-$). Strong solutions commonly used as disinfectants are admixtures of molecular chlorine and hypochlorous acid. Dilutions found in water and sewage treatment are mixtures of hypochlorous acid and hypochlorite ion. The hydrogen ion concentration of the solution determines which compound is formed.

At low pH values free available chlorine exists in solution largely as hypochlorous acid (HOCl). The hypochlorite ion ($OCl^-$) predominates at pH above 7.5 and at pH above 9.5 free available chlorine occurs almost entirely as the hypochlorite ion.

Chlorine as hypochlorous acid is the most rapid form of the bactericide as shown by the work of Rudolph and Levine.[10] This study, using *B. metiens* spores, indicated that 25 ppm. of available chlorine at pH 6.0 was effective in $2\frac{1}{2}$ minutes at 20°C. but required $35\frac{1}{2}$ minutes at pH 9.4. A similar concentration of chlorine at pH 10 was effective in 8 minutes at 50°C. but required 135 minutes at 20°C.

The destruction of bacteria by chlorine is a complicated process including oxidation of the cell contents and direct combination with the protein, causing precipitation of albumens. Direct reaction is usually by replacement of the unsaturated compounds in the cell structure with chlorine. A secondary oxidation of these compounds and their chlorine derivatives also takes place. Formation of these new compounds destroys enzymic action and, subsequently, life in the cell.

Presence of any organic compound will decrease the bacteriocidal effect of chlorine. Faber[5] in a recent review has stated:

> ". . . The intensity with which any oxidizing agent enters into chemical reaction is measured by its oxidation potential . . . . When chlorine combines with other substances its oxidation potential is reduced or may be completely neutralized. Chlorine reacts with ammonia to form chloramines and with other organic nitrogen compounds to form chloro-derivatives. With many forms of organic matter, particularly the hydrocarbons, chlorine addition products are formed."

## HYPOCHLORITES

Calcium hypochlorite was used to deodorize sewage in England as early as 1854[4] and in 1885 was recommended by a committee of the Amer. Public Health Assoc. as the cheapest efficient disinfectant available.[13] It was first applied to disinfect the Maidstone, England, water distribution system following an outbreak of typhoid fever in 1897. In 1906 Phelps utilized it to disinfect sewage and in 1910 Darnell experimented with gaseous chlorine for the disinfection of drinking water.

Routine disinfection of a water supply by the use of hypochlorites was

initiated in 1908 by George A. Johnson at the Bubbly Creek filter plant of the Union Stock Yards Company in Chicago, Ill. The Boonton water supply for Jersey City, N. J. was the first municipal supply to be so treated (1908). Liquid chlorine was developed for disinfection of water supplies in 1912 and by the use of modern equipment this procedure has become standard practice.

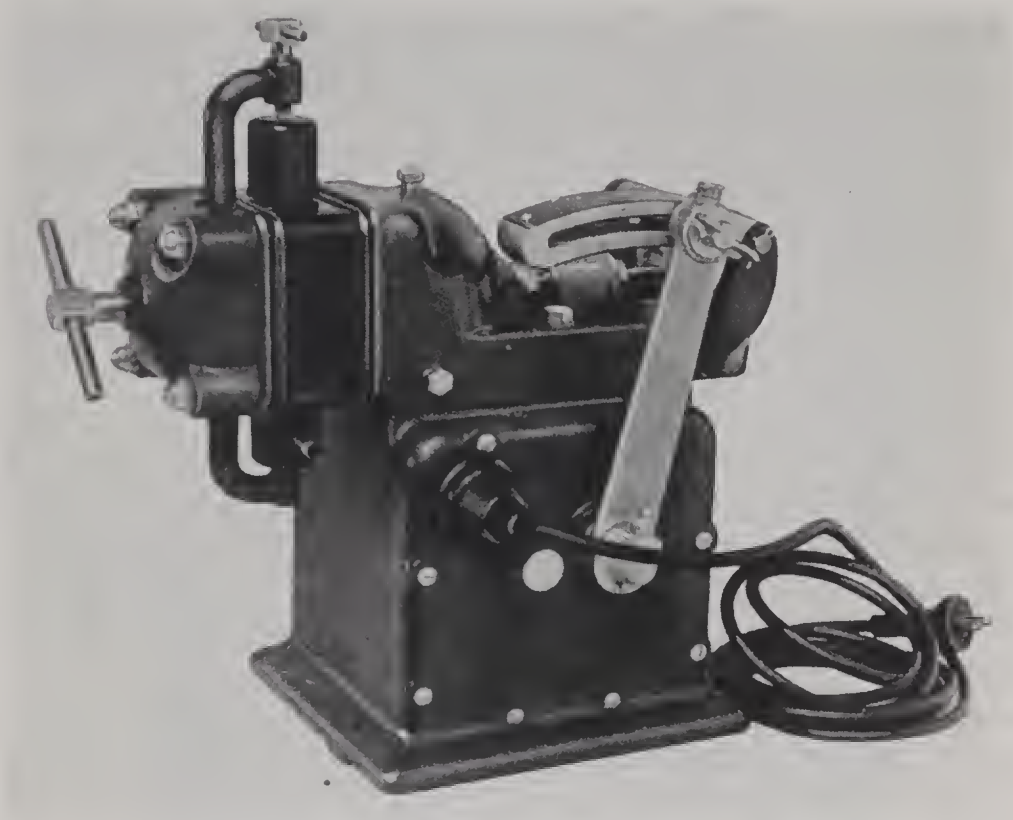

FIG. 3. Hypochlorinator. (Courtesy, Wallace and Tiernan Co.)

Bleaching powder, chlorinated lime, is an oxychloride decomposing in water into calcium hypochlorite and calcium chloride:

$$CaO + 2Cl \rightarrow CaOCl_2$$
$$2CaOCl_2 + H_2O \rightarrow Ca(OCl)_2 + CaCl_2 + H_2O$$

These hypochlorites generally have from 25 to 35 percent available chlorine content when made, but in the presence of moisture and heat this is rapidly depleted. Stabilized calcium hypochlorites—sold under such trade names as HTH, Pittchlor, Penchlor, etc.—which vary in strength from 50 to 70 percent available chlorine, have largely replaced the less stable chlorinated lime in most operations. These products show negligible loss of chlorine content over extended periods of time when stored in tightly closed containers and therefore are much more dependable and less costly sources of chlorine.

Sodium hypochlorite solutions, prepared by passing chlorine into caustic soda solutions are also available. They may have an available chlorine content of as high as 17 percent although many of the commercial bleaches contain only 3 to 5 percent.

## CHLORAMINES

Although known chemically for many years the various compounds collectively known as chloramines were not recognized as disinfectants until 1916. Dakin and Cohen[3] determined that para-toluene-sodium-sulfochloramide was an effective bactericide, did not combine easily with organic matter, released available chlorine slowly and was a good antiseptic for wounds. Compounds containing this chlorine radical dissolved in weak alkaline solutions are used to sanitize utensils, glassware, dishes and food equipment. The slow release of chlorine restricts its use to conditions allowing extended contact periods. It is therefore not an effective germicide when used as a contact rinse.

The slow release of chlorine led to the use of chloramines for water disinfection. Chloramine treatment has the advantage of providing delayed sterilization and when applied to the *filtered* water gives up hypochlorous acid so slowly that the available oxygen does not immediately react with organic material. Therefore, the formation of substitution products is prevented and a residual chlorine sufficient to kill bacteria is maintained. Chloramines also prevent the formation of objectionable tastes in water supplies sometimes experienced with chlorine.

Considerable research has been undertaken to explain the characteristics and disinfecting action of these chloramines. It has been established that at pH values averaging 7.0 mixtures of mono and dichloramines prevail. Dichloramine is lost in direct proportion to the increase in pH value and at 9.5 only monochloramine will be found. It is believed that the dichloramine is the more active disinfecting agent; therefore, fastest reaction will be obtained when the pH is below 7.0.

Chloramines are not as effective bactericides as free available chlorine. Results of a study by Butterfield and Wattie[2] suggest that:

> "The length of time of exposure of the bacteria in water to chloramine and the amount of chloramine present are primary factors governing the rate of bacterial kills . . . . Thus to obtain a 100 percent kill with the same period of exposure required about 25 times as much chloramine as free chlorine, and to obtain the same kill with the same amounts of chlorine and chloramine under the same conditions required approximately 100 times the exposure period for chloramine. . . ."

In solutions having lower pH values than 4.4, nitrogen chloride is

formed. This compound does not have germicidal properties. The chemical reactions are:

$$3HOCl + NH_3 \rightarrow 3H_2O + NCl_3$$
$$2HOCl + NH_3 \rightarrow 2H_2O + NHCl_2$$
$$HOCl + NH_3 \rightarrow H_2O + NH_2Cl$$

Since the pH value of most waters is between 4.4 and 8.5, a mixture of mono- and dichloramines is generally found in practice.

The Dakin type chloramine solution is prepared commercially and is obtainable as a liquid. Chloramine formation for water supplies, sewage treatment, swimming pools, etc., is obtained by introducing either gaseous or aqueous solutions of ammonia into the water followed immediately by the correct amount of chlorine. "Standard" equipment is utilized requiring a minimum of skilled attention.

### Application

For the disinfection of water supplies, sewage, industrial wastes, and swimming pools, chlorine is supplied in steel cylinders containing 100, 150, and 2,000 pounds. The gas is drawn off by its own vapor pressure or by suction and is fed into the liquid being disinfected. With modern equipment designed for accurately controlling and measuring gaseous chlorine, this procedure has proved to be the most generally acceptable and dependable method of disinfection. This equipment may even be made automatic in operation so that the chlorine dosage varies in proportion to variations in water or sewage flow. Such equipment is complicated and should be under the control of properly trained operators.

Since calcium hypochlorite and chlorinated lime are dry powders, solutions must be made before the chlorine can be used in treating water or sewage or in sanitizing equipment, dishes, etc. The common practice is to prepare a strong solution of chlorine and allow the insoluble materials to settle. The clear liquid is decanted or siphoned off and diluted to give a solution of 1 to 5 percent, as desired. Solutions of the high test hypochlorites can be made directly to give stock solutions of 1 to 1.5 percent chlorine

Since solutions of chlorine are highly corrosive, earthenware crocks, rubber-lined tanks, or glass jars should be used for storage. Wooden barrels can be used but the chlorine will attack the wood. Glass, and hard rubber, are satisfactory materials for feed lines.

Sodium hypochlorite is usually obtained in aqueous solutions and can be used immediately as received.

## BROMINE

Bromine is finding limited but increasing acceptance in the treatment of swimming pool waters.

### Advantages of the Halogens

Chlorine possesses certain advantages in public health work. It is generally available in one form or another and its action can be predicted with accuracy. Its chief advantages exist in the easy means of determining the concentration in water. In water work, particularly in emergency situations, chlorine has the great advantage of remaining an effective bactericide for an extended period of time after addition to the water. Neither ozone nor ultraviolet radiation possesses this virtue. Under crude conditions when contamination of drinking water in containers or tanks

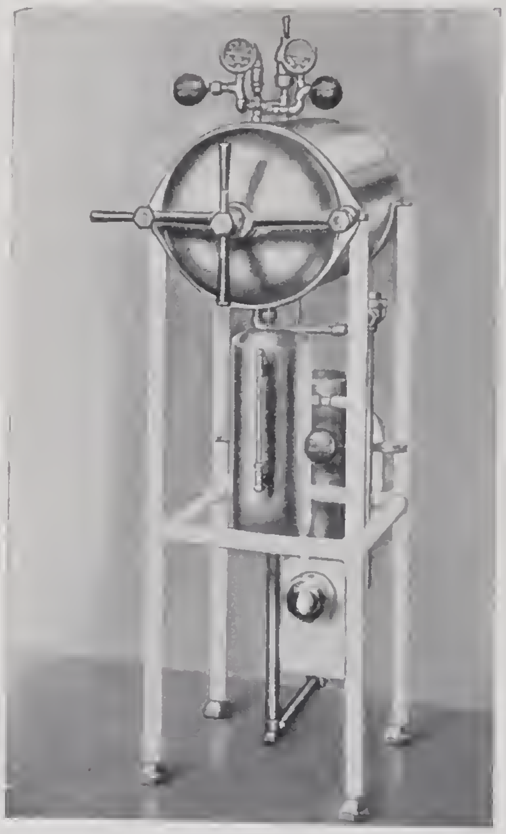

Fig. 4. Sterilizer. (Courtesy, Wilmont Castle Co.)

cannot be avoided, an effective residual chlorine content can be maintained, assuring safety of the water at all times.

## HEAT

"No living thing can survive 10 minutes direct exposure to saturated steam at 249.8°F. which is attained under ideal conditions at sea level with 15 pounds in a steam pressure sterilizer."[7]

Heat is the basic protection for surgery. It has been demonstrated that vegetated pathogens die in 2½ minutes at 249.8°F. and spores rarely live longer than 5 minutes. When moist steam completely fills a sterilizer, without air pockets, the usual sterilization of 15 pounds for 15 minutes is adequate. Dry air is less effective than moist heat and used only when

steam under pressure is impractical. Exposure for 60 minutes at 320°F. gives comparable sterilization to the steam procedure noted above.

Modern canning has resulted from the experiments of Appert in 1804[1] who noted that food heated to definite temperatures did not spoil when kept in sealed containers. Commercial canning was begun in America in 1821 but not until 1860, after Pasteur had demonstrated the killing of bacteria by heat, were the principles of sterilization understood. The application of these principles placed this industry on a scientific basis.

Some foods, particularly those having acidic characteristics, permit a wide range of heat control; with others this range is narrowed to avoid sacrifice of flavor and color. Neutral or alkaline foods are harder to heat sterilize than acidic types. The rate of heat penetration through a can of food is a function of time, temperature and food characteristics. Each substance has a more or less typical heat penetration curve.

## PASTEURIZATION

As defined by the "Standard Milk Ordinance" pasteurization is the heating of every particle of milk to at least 143°F. and holding at such temperature for at least 30 minutes or to at least 161°F. and holding at such temperature for at least 15 seconds in approved and properly operated equipment.[11] This latter method of pasteurization is known as "high temperature short time" (HTST).

Careful tests in laboratory and commercial milk plants, confirmed by over 20 years experience, have shown that the heating of milk to temperature of 142°F. for 30 minutes makes it safe from pathogens. The mechanical difficulty of designing, building, and operating pasteurization equipment with assurance that every drop of milk will be heated to the full temperature of 142°F. has led to the general adoption of 143°F. as the required temperature. Since the effect of heat is dependent upon the temperature and time, higher temperatures can be used for shorter periods of time. The "flash" pasteurizing temperature, 161°F. for 15 seconds, is based on this relationship.

Pasteurization means that the liquid has been heated to sufficient temperature for sufficient time to kill all pathogens. This does not produce sterility. For example, milk contains many organisms which vary in their thermal resistance together with spores that are difficult to kill. The tubercle bacillus which is the most heat resistant of the pathogens found in food, is killed by exposure to a temperature of 140°F. for 20 minutes. For this reason the tubercle bacillus is used as the test organism in determining pasteurization efficiency. There are many harmless organisms in foods which are not killed by pasteurization. It is desirable that lactic acid producing bacteria remain alive since their reproduction and growth,

and subsequent souring of the food, prevents the growth of more objectionable putrifying organisms.

Pasteurization of a liquid containing high bacterial counts should produce a large reduction in the number of bacteria. If this does not occur, the product is probably contaminated with a heat resistant organism, or the process is at fault. Heat resistant organisms are classified as "thermophiles" if they grow and reproduce under normal pasteurizing conditions. "Thermoduric" organisms are not killed by pasteurization but their growth and reproduction is retarded.

Use of pasteurization for wine and beer is increasing in importance for the purpose of reducing bacteria, yeasts, and molds. Temperatures between 115°F. and 130°F. with a 10 minute holding period are adequate; a clear liquid without noticeable change in flavor results.

## UTENSIL SANITATION

Hot water used to sanitize dishes, glasses, cooking utensils, and other food equipment is effective under controlled conditions. Initially, the utensils should be scraped free of large food particles and then cleaned with a good detergent in hot water between 120°F. and 140°F. Rinsing of the clean articles with clean hot water at 170°F. for not less than 1 minute is *bactericidal.* This procedure does not produce sterilization but pathogens are killed and the utensils made safe for use.

## QUATERNARY AMMONIUM COMPOUNDS

In 1916 Jacobs, Heidilberger and others of the Rockefeller Institute observed and reported on the bactericidal properties of the quaternary ammonium salts of hexamethylenetetramine. Nothing came of this work until 1935 when Domagk called attention to the fact that these compounds were both germicides and antiseptics.[6] From then on the knowledge of these new compounds has grown considerably. Several characteristics make the quaternary ammonium compounds particularly attractive for sanitation procedures. In recommended dilutions they are highly soluble, and they are tasteless and colorless. They have low toxicity and do not corrode metals or rubber more than does ordinary tap water. They are surface active, detergents, and wetting agents, although the wetting properties are much better than the detergent activities. They are generally placed in the "cationic detergent" group. Another distinct advantage of the quaternaries that make them good for sanitizing operations is the fact that there is less interference with their action from organic matter in the water than is the case with such an agent as chlorine.

There are of course some disadvantages to the quaternaries. The chemical composition of the tap water in which they are used will have a marked

effect on them. When used with an anionic detergent (soap) they are found to be incompatible. Mineral acids in solution will cause precipitations with the quaternary ammonium products. Calcium and magnesium hardness reduces their effectiveness greatly. The amount of the different compounds necessary to produce a 100 percent kill of *E. Coli* in 1 minute was observed with three different waters.[12] The results were as follows:

| Compound Designation | ppm. required to produce 100% kill of Esch. coli in 1 min. when compound was dissolved in | | | ppm. Recommended for Use by Producer |
|---|---|---|---|---|
| | Pure Water | Cincinnati, O. Tap** | Norwood, O. Tap*** | |
| A | 20 | 100 | 250 | 234 |
| B | 10 | 70 | 220 | 190 |
| C* | 5 | 500 | 3200 | 78 |

* Compound C differs from B in that a good detergent has been added to C.

** Approximately 154 ppm. hardness by soap hardness test.

*** Estimated as a 445 ppm. hardness.

Evidently in pure water the detergent enhances the bactericidal efficiency of the active agent and in good tap waters the combination of detergent and interfering substances practically destroys all bactericidal action.

Further investigation has shown that the addition of small amounts of alkaline detergents or sequestering agents will enhance the germicidal action when otherwise the presence of calcium or magnesium salts might have reduced the effectiveness markedly.

The quaternary ammonium compounds have been used extensively in restaurant, dairy and food canning operations. Other uses of the various compounds are of interest to public health people. It has been found that the quaternary ammonium compounds prevent the production of ammonia from urinary urea and so are beneficial as a rinse for diapers to prevent diaper rash. The New York City Department of Health has approved such use. They have shown promise as an agent to be used in washing swimming suits at commercial pools where public health requirements call for bactericidal treatment of the suits.

Lawrence[6] lists 80 different trade names under which the quaternary ammonium compounds are sold. He lists 30 different chemical compounds as being used. Before approval is extended for the use of any specific detergent of this class, its effectiveness in the water in which it will be used should be demonstrated and the required concentration determined. The value of each detergent must be determined.

Colorimetric tests for determining the concentration in any rinse solution have been developed. Convenient test papers are also available.

## PHENOL AND CRESOLS

Phenol has been used as a general disinfectant for many years. However, emulsions of ortho, meta and para cresols having soap or alkali as the

base are now extensively utilized to sanitize toilets, barn yards, and similar areas.

Well saponified cresols give a clear solution upon dilution with water and have a bactericidal efficiency comparable to phenol. They are stable compounds, very effective against vegetative cells but only moderately so against spores. They are not inhibited by organic matter and their soapy characteristics make them useful in cleaning. Their odor has psychological value in this respect giving a sense of cleanliness not attained by other soaps.

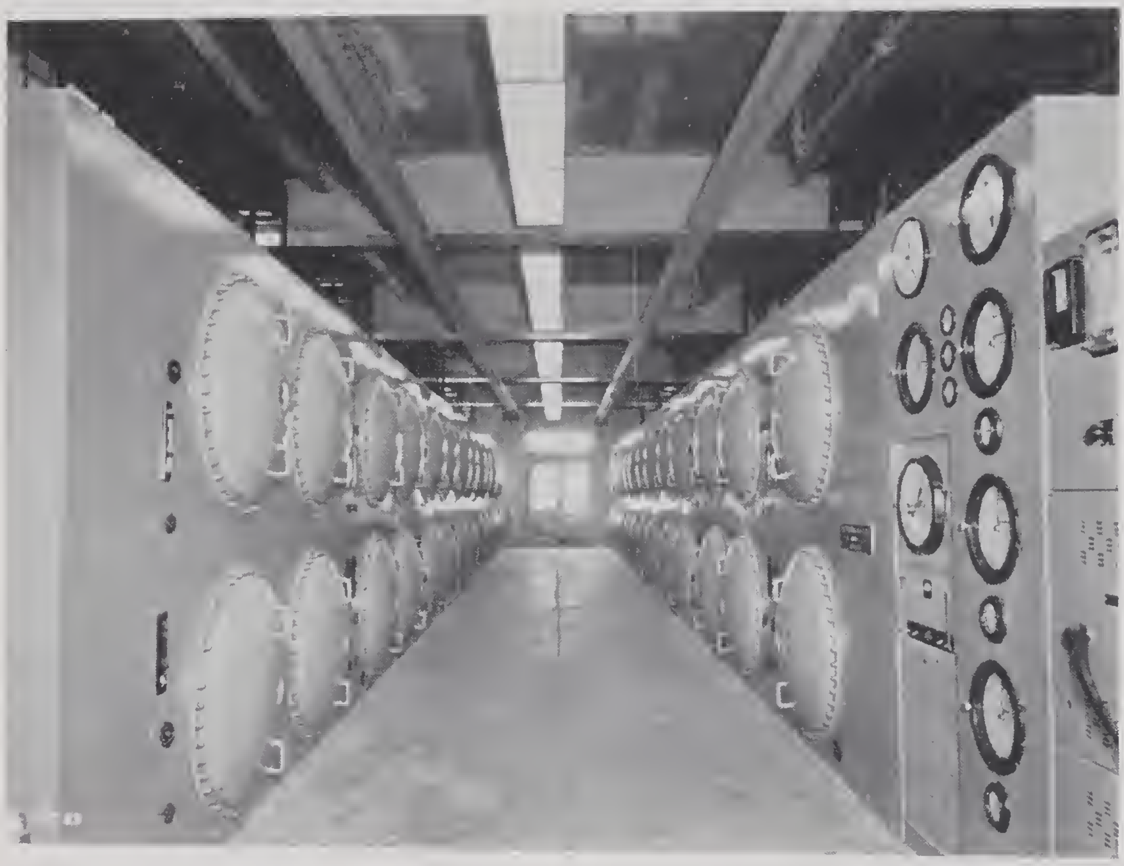

FIG. 5. Ozone generator, Belmont Water Purification Plant, Philadelphia, Pa. (Courtesy, The Welsbach Corporation.)

## OZONE

Ozone is an active oxidizing agent having the chemical formula of $O_3$. It is not an article of commerce but is generated by passing cleaned, dried air between electrodes connected by a high tension electric circuit. The silent electric discharge taking place in the air converts a fraction, usually about one half percent, of the oxygen present into ozone. The generation plant is elaborate, costly, and requires skilled operation.

Ozone is an unstable gas with each molecule breaking down to liberate one atom of nascent oxygen. Immediately after generation it is dispersed into the air or water under treatment. In sufficient concentrations it is an

effective bactericide but the gas must come in direct contact with the organisms to destroy them. It is toxic. Fish are killed when a heavy dosage is present in water and highly ozonated air is deleterious to animals when breathed for considerable periods.

Some effort has been made to use ozone generators to purify air in buildings. Concentrations usually are insufficient to destroy the bacteria in the air or be toxic to persons breathing it. Atmospheric odors are oxidized giving a clean fresh odor to the room.

Ozone has found limited use in Europe and in the United States for the disinfection of water and for taste control. With this disinfectant the water must be free of turbidity and a residual concentration of ozone must be maintained for 10 minutes. Contact time will vary with the temperature, warmer water requiring longer contact time.

## ULTRAVIOLET RADIATION

Bacterial action of sunlight is due to the emission of ultraviolet rays shorter than 3100 Å. These rays are subsequently absorbed by the protoplasm of the cell producing death by oxidation of the enzymes. In rural areas with high temperatures, sunlight is an effective germicide.

The chemical action of ultraviolet light depends upon the intensity and length of the wave. The source of the light waves has no influence upon their action and artificial light producing rays of the same length and intensity is as effective as sunlight. The advantage of artificially produced ultraviolet light is that the intensity and length of the wave may be constantly maintained with consequent controlled bactericidal action. The recent development of an economical mercury vapor lamp giving emissions of 2537 Å and having an average life of 4,000 hours has increased the potential use of ultraviolet radiation.

Bactericidal action is limited to surfaces exposed to the rays since the disinfecting reaction is photo-chemical with destruction of the enzyme. Opaque fluids cannot be disinfected by this process since penetration is impossible. A radiation of 2537 Å is the most efficient but waves between 2540 Å and 2800 Å are bactericidal.

Ultraviolet radiation is used commercially to destroy bacteria, yeasts, and molds in sugar, meat, and bakery products. Hospital and operating rooms are occasionally exposed to treatment to reduce the number of organisms present in the air.[9] Much work has been done to determine the value of ultraviolet radiation in the reduction of pathogenic organisms in the air of general living and working rooms. Some recent work indicates beneficial results in the reduction of some communicable diseases in school rooms. Most authorities do not accept the value of general air sterilization by use of ultraviolet irradiation.

Gram negative non-sporulating rods are readily destroyed by ultraviolet rays. *Staphylococcus aureus* and *Streptococcus pyogenes* are resistant, and spore formers are even more resistant.

This disinfection procedure has a practical application to water purification when economic considerations are unimportant. Clear colorless water is passed between a battery of lamps emitting rays of 2500 to 2600 Å. Penetration of these rays is effective for 92 percent of emission with a 3 inch depth of distilled water and for 5 percent with a 24 inch depth. This procedure is used in a few manufacturing establishments and swimming pool installations. The use of ultraviolet radiation for treatment of eating utensils, once popular in some communities, is now seldom found, because of the practical difficulties in its use.

FIG. 6. Ultra violet irradiation of air and surface of processed fruit in vats to prevent fermentation of yeast and mold scum. (Courtesy, General Electric Co.)

## OLIGODYNAMIC SILVER

It was noted by Naegeli in 1893 that silver in high dilution, 0.01 ppm., possessed bactericidal properties. Copper was also found to be effective in dilutions of 77 ppm. The bactericidal action is caused by the ionization of these metals.

In this disinfection method, using silver, water is passed between electrically charged silver plates with dispersion of the silver ions into it.

Dosage of 0.1 ppm. have been utilized for treating swimming pool waters. Higher dosage will create an opalescence caused by the formation of colloidal silver chloride. Economically, the method is not practical for the treatment of water supplies.

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## Chapter III

# THE SANITARY SURVEY

A sanitary survey is an analysis of the physical environment having an influence on the public health of a community. Its purpose is to indicate problems and so permit the development of the most practical procedures by which the health of the inhabitants may be improved and existing diseases controlled and eliminated through manipulation of the environment.

The initial step in conducting the survey is the development of a working plan and determination of sources for needed information. The plan must be carefully thought out. Information will be obtained from local governmental authorities and civic agencies through personal conferences; letters and questionnaires seldom bring the information needed. Personal inspections must supplement the information obtained from these sources. The data collected must conform to the object of the survey and extraneous information must be discarded. Careful preliminary planning will make the actual survey easier.

The survey must be under the direction of a person of broad training and experience. A sanitary engineer with a knowledge of the community and of epidemiological problems and the ability to solve them should direct the work. The necessary personnel can often be secured from the State Department of Health if a real need for the survey can be shown. Outside consulting engineers are frequently employed to conduct the entire study or parts of it.

Publicity is an important factor. When properly utilized it is an asset but if it is allowed to degenerate into "scare headlines" and biased reports, as information becomes available, it is worse than useless. The cooperation of civic organizations must be obtained for its moral value and also as an aid in obtaining the needed supply of manpower required for conducting those portions of the survey non-professional persons can do. An advisory committee of civic leaders is valuable since it can be kept informed concerning conditions in localized areas and so serve as the force demanding correction of conditions found and furtherance of the health department program. Members should be selected with care, on the basis of their acceptance of the health department goals and their influence as citizens.

## GENERAL INFORMATION TO BE OBTAINED

The community should be classified as to its geographic and climatological environments. These are of particular importance for the evaluation of

and comparison with conditions in other localities having similar physical characteristics. Climate and rainfall have a decided influence on the activities and occupations of the people and should be noted. The population as shown by the latest census including information on racial groups and educational levels should be recorded. Both are important factors in the economic life and have an influence on a health program. Concentration of the population in limited areas should be noted. These data will determine the need for water supply, sewage disposal, refuse removal, etc. They will also indicate to some extent possible foci for certain types of epidemics. If the community is expanding into an adjacent newly developed urban territory with population decline in older sections, development of blighted areas may be indicated. The unfavorable economic condition of such sections always react adversely on tax resources and on the operation of good health programs. The survey should uncover population shifts of importance.

The types of industry comprising the bulk of business life should be surveyed. These have a very important bearing upon the economic life. Occupational hazards peculiar to dominant industrial or commercial interests should be cited.

The morbidity and mortality rates indicate the most important diseases present and show the need for sanitation improvement. They are a basic factor of the survey. Coupled with population density in given sections, these data will show sources of infection and potentially dangerous areas.

## WATER SUPPLY

The adequacy of the source, purification processes and storage of treated water must be evaluated under maximum and average consumption. The extent to which the community is supplied by the public system and probable expansion of it are vital factors to be noted. The per capita consumption over a period of years should be studied in relation to future water requirements and potential sources of supply.

The efficiency of the purification process and a review of operating records to determine whether or not the supply meets public health standards is important as a guard against outbreaks of water-borne diseases. The use of bottled waters or private water supplies for drinking purposes should be determined. The pollutional hazards of private supplies should be investigated and the cross connection program evaluated.

The ability and administrative efficiency of the department personnel is an important factor, as is the influence of political control or merit system if the water system is municipally owned and operated. This will apply to all other departments surveyed.

## SEWAGE DISPOSAL

Unsewered areas and the type of sewerage system and effect upon it of rainfall should be noted. A tabulation of the capacity of interceptors, trunk and outfall sewers should be made and noted in relation to the population density for the section served by each. These data can be obtained from maps of the sewerage system. An accurate map of the sewerage system should be available.

The volume of industrial waste discharged into the sewers and its effect upon the treatment process must be considered when reviewing the operation and adequacy of the treatment works. These wastes will also directly influence the type of treatment that may be employed. The pollutional hazard introduced into the diluting watercourse should be evaluated and, if serious, installation of proper treatment facilities recommended. The per capita load should be computed to determine if the treatment works are overloaded or capable of handling increased loads.

Expansion plans should be reviewed to determine if the diluting watercourse is capable of assimilating an increased load with the existing treatment process or by change in procedure. Community growth may be permanently curtailed by inadequate facilities for the future disposal of sewage.

The number and condition of privies, cesspools and septic tanks in unsewered areas should be recorded and necessary corrective action suggested. Particular attention should be paid to the possible pollution of water supplies from the private sewerage systems.

## REFUSE DISPOSAL

Collection practice and cost per capita should be noted. Complaints of poor service must be carefully evaluated to determine the adequacy of the collection system. The sanitary conditions of final disposal should be investigated to determine whether or not the best procedures are utilized. Adequacy of health department supervision should be noted.

Uncontrolled dumps and hog feeding frequently give rise to serious sanitary hazards. Special attention should be given to this type of disposal.

## MILK SUPPLY

Survey of the distribution program will include pasteurization and farm inspection. The survey will disclose any variance from the provisions of the "Standard Milk Ordinance" or its equivalent. "Spot" inspections of dairy and pasteurizing plants, and farms should be made for assurance that equipment, methods of operation and conditions are sanitary and satisfactory. Marketing of milk from tuberculin tested herds and the

handling of raw milk by farmers should be investigated. The survey should include an investigation of the production and distribution of ice cream, cheese and butter processing establishments.

## RESTAURANTS AND FOOD ESTABLISHMENTS

The efficiency of restaurant inspections and conformity to standard codes must be evaluated. Operating methods, cleanliness and adequacy of equipment are the principal features to be investigated. The number of safe and insanitary establishments must be determined. The physical examination of food handlers is unimportant as a routine procedure but should be used upon employment to detect sick persons and carriers. Methods of food handler training by official agencies and by industry should be noted.

## PUBLIC BUILDINGS

Enactment of a modern building code is one of the objects of the sanitary survey. Where a code is in force that portion concerning sanitation should be reviewed and its enforcement evaluated. The survey will disclose the type of ventilation practiced in schools and other public buildings, together with the adequacy of toilets and washrooms. The lighting of public buildings and maintenance in a clean and sanitary condition should be noted.

Slum clearance and sub-standard housing problems should be surveyed on a broad scope in relation to population density and transportation facilities together with the adequacy of other public utilities.

## SWIMMING POOLS

The number and operating efficiency of community swimming pools as well as retention of needed records of operation are important factors. Pools conforming to standard regulations should be determined and remedial action suggested to eliminate insanitary ones. Notation should be made describing the equipment and ability of operating personnel. The numbers of people using each pool should be recorded.

## INSECT AND RODENT CONTROL

The prevalence of insects and rodents should be recorded and the physical conditions conducive to their breeding surveyed and suggestion made for an eradication program. Prevalence can be determined by personal observation, official reports or observations of citizens of the community.

## HEALTH DEPARTMENT

The health department is the established agency to protect and promote the public health. In its organization and civic contacts should be found

the required personnel to accomplish its objectives. The sanitation program must be carefully considered as to needs and the efficiency of operation evaluated. The cost per capita and distribution of these funds between the various sections of the health department must be determined. The laws which empower the department to act should be reviewed and if found inadequate recommendations for improvement made.

Responsibility of the local health department to either state or county control should be noted since dual responsibility has a tendency to create laxity in administration.

## GOVERNMENT

The type of local government, whether city manager or mayor and council should be reported. The use of merit system for employee procurement and control and interference by politicians in administrative actions should be noted. The allotment of funds from municipal sources should be compared with that of similar communities. The utilization of financial assistance from state and federal sources should be evaluated.

## THE REPORT

The report must be concise but supplemented by comprehensive data in the form of tables, charts and maps. Recommendations for remedial action must be included for all objectionable features noted.

Capitalize immediately on public interest. Civic organizations are an important factor in disseminating the facts learned. Public interest must be maintained until all remedial action has been accomplished.

The forms developed by a committee of the American Public Health Association are an excellent guide for recording information.[6]

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## Chapter IV

# FOOD SANITATION AND PUBLIC HEALTH

The object of the regulatory control by the health department of the food supply of a community is primarily to prevent illness, and possibly death, from spoiled or contaminated foods. Bacterial contamination or spoilage may occur at the source of production, during transportation, in storage, or during manufacturing processes. The health department attempts to prevent exploitation of the public through the sale of inferior, misbranded foods. It is also interested in protecting the public against foods that may have harmful diluents or substitution products in them.

The obligation to produce safe foods rests upon the producer, processor or manufacturer. Regulatory control is the responsibility of health departments, particularly the local health agency. The Food and Drug Administration of the Federal Security Agency has responsibility for the control of foods in interstate commerce under the Federal Food, Drug, and Cosmetic Act of 1938. In many states the department of agriculture has certain responsibilities; other state agencies may also have special roles.

The majority of illnesses caused by the ingestion of spoiled or contaminated foods are not reported or officially noted. This is due partly to the absence of state laws requiring reporting and partly to the fact that medical attention is obtained only in the more serious cases or outbreaks. It is therefore difficult to estimate the incidence of such illnesses. The magnitude of the problem of control can be inferred from the fact that there are 160,000 restaurants, cafeterias, lunchrooms, and soft drink and ice cream stands; more than 80,000 drinking places that serve meals; 50,000 taverns, bars, and clubs that do not serve meals; and 40,000 drug stores and soda fountains in the United States.[1] In addition to these places serving food directly to the public there are many others preparing foods on a large commercial scale.

A common misconception has been the ptomaine poisoning idea that certain foods on spoiling produced specific poisons or ptomaines. This concept ignored bacterial action and considered spoilage a normal phenomenon peculiar to all foods. It is known now that this concept was faulty and that food poisonings are caused by one of three different general contaminants:

1. *The salmonella infections.* Illness is caused by the introduction of these living organisms into the body where they establish a definite infection. There is usually a 12 to 24 or 36 hour interval between eating the infected foods and the symptoms of illness. The source of the original infec-

tion in the food is usually from the discharges of a food handler or the excreta of rodents. There is circumstantial evidence that implicates the cockroach as a mechanical carrier of infection. *S. enteritidis*, *S. aertrycke*, and *S. simpestifer* are members of the Salmonella group. If these organisms in food are killed by heating there is no danger of infection.

2. *Toxins produced in the normal multiplication and growth of certain organisms in food. Staphylococci* from infected cuts and other hemolytic cocci, in certain foods will produce enterotoxin types of poisons to which man is highly susceptible. The interval between eating the infected food and the first symptoms is 2 to 6 hours. This is not a true infection in man but represents the effects of toxins produced by organisms that normally are not pathogenic in the human intestinal tract. Heating will kill the responsible organisms but will not destroy the toxins already formed. Cream filled pastries, salads, and meat products are common classes of foods involved.

3. *Botulism.* Although this "infection" is typical of the group above, it has an importance of its own. Like the staphylococcus toxin food poisonings, botulism is caused by the toxin produced by organisms growing in the food. In this case a specific organism, *Clostridium botulinum*, is responsible. The *Cl. botulinum* is a spore-former and boiling temperatures will not kill the spores. Fortunately, the organism does not grow well in acid mediums and the toxin is destroyed by boiling. Home-canned products not heated adequately during the canning process are the normal source of infection. (Heating at 248° F. for 10 minutes will destroy the spores.[2] This temperature is usually obtained by heating under pressure.)

Food poisoning, using the term in its most general sense, also occurs from the introduction of chemical poisons into foods. Careless handling and storage in kitchens of insect and rodent poisons has been the leading factor in most poisonings of this type. Dack[6] lists 10 different chemicals in his table of characteristics of gastrointestinal upsets from chemical poisons. These include antimony, barium carbonate, sodium flouride, zinc, and arsenic. Several of the chemicals were introduced into the food by the action of the foods themselves on the container, i.e. acid foods on zinc, acid liquids on cadmium plated utensils, and antimony from the enamel of cheap cooking utensils.

The United States Public Health Service[22] has tabulated information on reported outbreaks of food poisoning. Between the years 1938 and 1948, inclusive, 376 outbreaks reported have been attributed to milk and milk products; 2,703 have been traced to other foods; and 215 have been considered food poisonings of undetermined origin. The results of these outbreaks include 134,028 cases of illness and 584 deaths.

A sanitation control program in food handling establishments includes

consideration of exterior environmental appearance, clean interiors, cleanliness of equipment, good housekeeping, education of personnel in hygiene, insect and rodent elimination. Rating systems are frequently employed which are designed to show the factors influencing sanitary practice and the cost and responsibility of each separate department in a plant. Korff has shown "that educational methods are by far the most effective way to obtain results."[11] The punitive procedure while used as a means of last resort, is being replaced by training programs, conferences, and demonstrations of sanitary procedures.

This discussion of food sanitation includes consideration of some of the groups of foods handled; methods employed in various types of food preparation or preservation; and supervision of those places serving food to the public. Milk and milk products are treated separately.

## MEAT PRODUCTS INCLUDING POULTRY

Meat production is a highly technical industry. The large plants are engaged in world wide business and are under federal inspection while the local abattoir is under state or municipal control. The modern packing house is a combination of slaughter house, cold storage and freezer warehouse, smoke house, pickling plant and cannery. Fresh meats are among the most perishable of foods. Heat so greatly alters the character of meat that refrigeration has been adopted as the general method of preservation, although canned meats are a very important article of commerce.

### General Procedures

Prior to slaughtering, animals are usually inspected to eliminate the sick or fatigued and to ascertain if any communicable diseases are present among them. Poultry is held a few days before killing for observation and, if to be frozen, fed upon a buttermilk diet to remove objectionable flavors from the meat.

Cattle are stunned prior to slaughtering. Animals are killed by having their throats cut to facilitate thorough bleeding. Poultry are beheaded or stuck. After bleeding has been completed, cattle hides and organs are removed and the carcass dressed. Hog carcasses are scalded at 140° F. to loosen the hair which is mechanically scraped from the skin. Feathers are removed from poultry by rubbing after scalding in water at 160° F. or by "dry picking." A post-mortem inspection is made of carcasses and organs at local abattoirs under federal supervision. This inspection will detect gross pathology. Carcasses may be condemned in whole or in part; they may be withdrawn from any use as food or permitted to be used only for processed (canned) purposes. It should be noted that the usual post-mortem inspection of pork will not detect the presence of trichinae.

### Storage

As soon after butchering as is possible, meat should be cooled to a temperature that inhibits bacterial activity. This is one of the most important factors in its preservation. Immediately after being dressed, it should be placed in a cooler at 34° to 36° F. where it is rapidly chilled. Warm and previously chilled carcasses must not be mixed in the fore-cooler because slime will form on the meat surfaces from moisture condensation. One practice is to store beef in cold storage rooms at 34° to 36° F. for two to six weeks in order to produce a ripened or aged condition which improves the texture and flavor. During such storage autolysis, that is,

Fig. 7. Beef in cold storage. (Courtesy, Food Industries.)

auto-digestion of the meat, takes place to a slight degree, accompanied sometimes by an external growth of mold. The mold is thought to have no direct part in the aging process.

Solidly frozen meats may be stored satisfactorily for long periods of time, that is, a year or more, depending upon their character and the care in storage. Molds and bacteria develop very slowly, if at all, on the solidly frozen flesh, and the natural tissue enzymes are not seriously active at very low temperatures.

After slaughtering, pork, lamb, veal, and mutton are held for 72 hours before cutting. When held for longer periods they are frozen at 0° F. to −15° F. Poultry prepared for freezing is usually undrawn although there is an increasing demand for cleaned birds. Storage is maintained below 15° F. Recording thermometers are used to control temperatures in the fore-cooler, chill room, and frozen storage compartment.

## Detection of Decomposition

Decomposition of fresh or cold storage meats can be detected best by odor. Different meats have various natural odors. It is important for anyone in a regulatory position to have a knowledge of these natural odors so that he can detect abnormal odors and so that possible condemnation of sound meats can be avoided. The nose should be placed close to the meat to detect "off" odors. Only experience can give proficiency in the recognition of unnatural odors.

Large cuts of meat, particularly smoked or otherwise treated meats, may decompose around the joints of bones. A steel "trier", a slender rod, is used to sample the odor in these protected places. The trier is thrust into the meat until it strikes the bone. Immediately after withdrawal, the trier should be examined for any traces of off odors.

Meats should have a dry surface. Any pieces having a slimy covering should be rejected. Since slime forms best in areas protected from air circulation, those parts of the meat protected by over-lying joints should be examined carefully. The area under the wings of poultry is a good example.

Any meat that shows insect infestation should be rejected. The infestation may be manifested by the presence of maggots or eggs. The best that can be said under these circumstances is that the meat has been improperly stored or handled in transportation.

Stale fish can be detected by odor or by the general condition of the flesh which should be firm to the touch. Sunken dried eyes indicate that the fish are not freshly caught.

## Curing

Large quantities of meat are mildly cured in the United States, and because of the mildness of the cure they must be held or transported under proper refrigeration. "Cured meats" in this discussion include all types of meat products that have been subjected to a curing process with smoke, common salt or brine, saltpeter, sugar, etc. Ham, bacon, tongues, frankfurters, bologna, and various types of sausage are some of the more common cured products. The processes of curing should be speedy and thorough to prevent microbial decomposition, especially when large cuts with much bone, such as hams and shoulders, are treated. Chilled meat is used. Temperatures in the curing rooms should be between 34° F. and 38° F. without excessive humidity. Curing vats must be covered to prevent contamination from exterior sources. The strength of the pickle should be tested at intervals and salt added when required. For a good cure the meat must be kept covered with pickle. It is the commercial practice to inject such meat with the curing pickle so that curing near the bone may be

hastened. If this is not carefully and efficiently done, hams and shoulders may "sour."

Only pickled meat or portions containing a very small amount of moisture are smoked. Smoke from different woods imparts specific flavors. Smoke house temperatures are held between 100° F. and 110° F. Meat being smoked must be hung to provide a good circulation of air between the pieces. Smoking is continued for about 9 days.

Cured meats are, of course, less susceptible to microbial spoilage than are fresh meats. Salt in high concentration is an effective preservative, and smoke contains chemical substances which reduce the rate of microbial growth in smoked products. But the word "cured" as applied to such products should not be interpreted as meaning complete protection against deterioration or spoilage. "Cured" meats if not properly handled and stored in the home, restaurant, or hotel may decompose and so cause serious illness to persons consuming them.

### Canning

The canning of meats as a commercial method of preservation began in the United States many years ago. Both fresh and cured meats are now canned in large quantities. The principal products are roast beef, corned beef, and the ground or chopped meat products frequently referred to as "deviled" or "potted" meats. The fresh meat or meat products which come to the canning department of the packing house are usually in a satisfactory sanitary condition.

The meat selected for canning is first cooked and boned and then packed into cans by hand or it is finely ground and packed by machinery. The general procedures for vegetable canning and storing as discussed on page 37 are practiced.

Chicken canneries have been established in localities where fresh poultry is available in relatively large quantities. Canned whole chicken and chicken products are processed under steam pressure for sufficient time to produce sterility and also to provide adequate cooking.

Temperatures and pressures higher than those used with fruits and vegetables are permissible in canning meats, since the flavor and texture are not impaired by over-cooking as is the case with fruits, vegetables, and marine products. In the rare instances of microbial spoilage of canned meats, the fact as a rule can be detected by the swelling of the ends of the cans or, when the can is opened, by the offensive odor, probably from some of the sulphur compounds of the meat.

Edible secondary fat products such as lard and oleo-stearine are chilled, ground and melted (rendered) at 150° F. to 160° F., clarified by centrifuging, packed into final containers and held under refrigeration until shipped.

Unedible fragments of meat, refuse, offal, and carcasses of dead animals are converted into tankage by steam rendering. These materials must be sent to the tank room without passing through the meat rooms. Tank rooms must not be directly connected to the packing floor.

Fresh meat contains a high proportion of protein, which is readily decomposed by bacteria which multiply with astounding rapidity in such nutrient materials as meat juices. For this reason, all utensils and equipment coming in contact with the meat should be thoroughly and frequently cleaned. Only hot water, strong cleaning agents, and scrubbing can be expected satisfactorily to clean metal equipment or wooden cutting blocks smeared with serum, blood, and fat. After cleaning, all equipment should be treated with a good disinfectant, such as chlorine or one of the quaternary ammonium compounds, or it may be sterilized with steam.

After cleaning, the walls and floors of meat dressing rooms should be sprayed with a chlorine solution having a strength of not less than 100 ppm. Coolers and refrigerator rooms should be kept clean and the floor occasionally sprayed with a weak chlorine solution to control odors.

The daily cleaning of rooms and equipment is of great importance. Where glazed tile walls, brick or concrete floors, or other impervious materials have been used in construction, this is easily accomplished by hosing. Rat-proofing of the building and the use of DDT or other suitable insecticide to control insects is necessary.

Toilet facilities, including lavatories, equipped with hot and cold water, should be provided for each sex. The toilet room should not open directly into the packing room. One lavatory per each 20 employees is satisfactory.

## MARINE PRODUCTS

All edible sea foods are consumed when fresh. Salmon, haddock, halibut, tuna, mackerel, cod, sardine, flounder, herring, shrimp, crabs, lobster, clams, and oysters are the principal marine products canned or frozen.

### Fish

From the time fish are caught until cooked they should be handled, transported, and stored under sanitary conditions. Fish must be chilled immediately upon removal from the water and while being brought to the fish houses for sorting and packing. During cold weather, storage without ice on ship board is practiced, but in warm weather fish must be stored in chill rooms, cooled with ice, or frozen.

Fresh fish must be kept cold until consumed. They must have the best of care in handling and be kept absolutely clean. Fish should be deposited in the fish house within 6 hours after being caught, unless they are frozen on ship board. They may be held packed in ice for 6 days but if to be frozen, freezing must be done within 3 days.

When fish are being packed for shipment, a layer of fine crushed ice is placed on the bottom of the barrel, then a layer of fish. Layers of ice and fish are alternated to within 1 foot of the top of the barrel which must then be filled with ice. A ratio of 1 pound of ice to 2 pounds of fish will keep the fish fresh for 2 days in warm weather.

Sound, properly packed fish may be held at 32° F. for 14 days since at this temperature fish do not freeze, nor does the ice melt. Refrigerator cars are kept between 38° F. and 45° F. when carrying fish in containers in which the fish are covered with chipped ice. Preservatives are occasionally incorporated with the ice to reduce microbial activity. Hypochlorites have proved successful as preservatives in England but have not been widely adopted by American fishermen.

Fish for marketing at distant points are usually quick frozen. This is accomplished by a modification of the plate surface freezer or by suspending the fish in brine at 7° F. from one half to 6 hours. After being frozen, fish are glazed by a dipping in clean, clear water just above the freezing point, followed by a quick withdrawal. This produces an air tight coating of clear ice about $\frac{1}{32}$ inch thick around the fish. After being glazed, the fish are stored at 0° F.

After washing and gutting and in some instances after the removal of the back bone, fish may also be canned, dry salted, pressed, pickled, dried or smoked. The processes used are analagous to those discussed for the preservation of meat and meat products.

It is essential that strict sanitary measures be employed throughout fish packing houses and on the boats. Water, ice, and brine must be kept free from contamination and meet standards equivalent to those set for drinking water. The floors, walls, and ceilings of work rooms in packing houses should be of impervious construction and the rooms and equipment cleaned daily. A germicidal bath must be given all equipment at the end of work each day.

### Crustacea

Other common sea foods include shrimp, crabs, and lobsters. They must be chilled immediately after removal from the water, kept well iced, and handled under strict sanitary conditions. Shrimp must be washed, then packed in crushed ice or frozen solid to keep for any length of time. Crabs and lobsters, if packed in ice, may be kept alive for 3 days after removal from the water.

Shrimp, crabs, and lobster are canned for markets too distant to permit sale as fresh food. They should be well iced promptly after being caught to inhibit bacterial as well as enzymic decomposition, and should be brought to the cannery as soon as possible after they are taken from the sea. In order to remove the outer shell without damaging the meat fresh shrimp

must be peeled by hand. These fish contain an active digestive enzyme which quickly produces suppurative sores on the hands of the operators or "peelers." It has not proved practical for the peelers to wear any type of gloves while working, so work shifts cannot continue longer than a few hours at a time. After being peeled, the fish are washed and immediately pre-cooked in boiling brine, which hardens or "fixes" the muscle tissue. The brine should be maintained at the boiling point; otherwise, the pre-cooking may become a process of bacterial inoculation. The shrimp are cooled on racks, then packed into cans by hand and heat processed, generally at 240° F. Packs covered with brine require less processing than the so-called "dry pack."

Like most other marine products, canned shrimp is highly susceptible to spoilage and, once the container is opened, should be consumed immediately or well refrigerated.

Crabs are boiled in 0.6 percent sodium bicarbonate solution until cooked, then washed in cold water and "picked." The meat is then washed in 1 percent brine. Lobsters are boiled in 3 percent brine for 30 minutes, cooled in 6 percent brine, and "picked." Both crabs and lobsters are hand packed into cans or glass containers. Processing is similar to that used for shrimp. Sanitation control comparable to that suggested for canning houses (see p. 43) is necessary to insure a satisfactory product.

## Mollusks

Oysters, clams, and mussels are the mollusks of interest. Oysters are grown in the brackish waters of bays and rivers along the Atlantic seaboard, Gulf of Mexico, and Pacific northwest. Generally, these waters are subject to surface runoff and consequent pollution, so that it has become necessary to restrict closely the areas from which these shell-fish may be taken.

Oysters from sewage-polluted waters have been the cause of many outbreaks of typhoid fever, necessitating general supervision of the industry by health authorities. An oyster-borne epidemic of typhoid fever occurring more or less simultaneously in New York, N. Y., Washington, D. C. and Chicago, Ill., in 1924 received widespread publicity, caused a loss of public confidence in the safety of this shell-fish and seriously reduced sales. To restore public confidence in the industry, the oyster growers requested the health authorities to formulate a control program that would make this shell-fish safe for human consumption. A basic policy was subsequently established by the cooperative efforts of health officials and representatives of the industry. The essential hygienic requirements to assure cleanliness and safety in marketing are:[21]

1. Shell-fish shall be marketed only from inspected and approved beds

located in water areas which are free of contamination from dangerous pathogenic organisms.

2. These products shall be under rigid public health inspection and marketed with sanitary procedures that will safeguard them from contamination or adulteration that would cause them to become unfit for food.

3. Each shipper must be licensed and issued a distinctive establishment number by the appropriate state health agency. Every shipment of shell-fish shall bear an approved tag showing the identification number of the shipper. If a lot is split into smaller quantities during wholesale transactions each portion must be marked with an approved tag bearing the number of the original shipper. (Thus, any retailer can quickly trace the source of shell-fish, should the need arise.) Shipping methods and storage procedures must be under the control of state or federal health agencies.

4. The shell-fish must conform to an established bacterial standard and meet food regulations.

Since establishment of this program the shell-fish growing areas are periodically surveyed by state or federal agencies. These sanitary and bacteriological surveys are mandatory for health department approval and should be made at least every 2 years or as frequently as required. Growing areas are classified as approved or restricted.[21]

Approved areas are free from human wastes or if such are present, they are diluted to such a degree that they are innocuous. The coliform organism density in the water, expressed as the most probable number (M.P.N.) shall not exceed 70 per 100 cc. as median of a series of samples collected from several sections of the area. Grossly polluted areas are those directly contaminated with sewage as shown when the coliform density in the water is greater than 700 per 100 cc. These areas are restricted and the taking of shell-fish from them is prohibited.

Moderately polluted areas are those showing indirect contamination with the coliform density in the water less than 700 per 100 cc. Shell-fish may be taken from moderately polluted areas during the hibernation period, when the water is not above 41° F. and when the coliform density of the shell-fish does not exceed 20 per 100 cc. Shell-fish may be removed from moderately polluted areas to storage in approved areas or in chlorinated sea water for biological cleansing. They must be held in the clean water at a temperature below 51° F. for not less than 7 days prior to sale. Special permission to transplant the shell-fish must be obtained from the health agency having jurisdiction. Tank installations for this cleansing of shell-fish is a relatively new development in the business.

Chlorination of storage water, in which the unshucked shell-fish are kept temporarily, to promote cleanliness and self-purging of disease organisms is advantageous. The practice of taking oysters from contaminated beds and attempting to disinfect them by more vigorous chlorination procedures is not considered safe. It may be said to have its counterpart in the practice of pasteurizing dirty milk.

When the *B. coli* M.P.N. exceeds 230 per 100 cc. for shell stock it is an indication of unfavorable conditions in handling or at the production areas. An immediate investigation by the supervising agency is required.

Although the standards establish the coliform M.P.N. as the criterion of safety, bacterial control of shell-fish and shell-fish growing areas is being based increasingly upon the density (M.P.N.) of the *Escherichia coli* organism rather than of the entire group. This organism correlates more closely with physical conditions as developed by the sanitary survey and is therefore a truer index.

Boats used for shell-fish collection should have their storage bins so located that bilge water or polluted sea water cannot come in contact with the catch. Human wastes must be collected in a water tight metal container and the contents disposed of in a sanitary manner ashore or discharged overboard at a point remote from the shell-fish grounds and approved by the supervising authority.

Shell-fish held in dry storage must be adequately protected from contamination at all times. This includes protection from flooding, rat proofing of the room, construction of the room with impervious materials and adequate floor drains to facilitate cleaning.

### *Canning of Oysters and Clams*

At the cannery oysters are loaded into iron crates, washed with a hose and wheeled into "steamers." These are retorts in which the oysters are killed with steam so that the shells open. As steam at ten pounds pressure is used, a marked reduction in the contamination on the shells occurs.

On the Eastern Seaboard clams are washed in rotary drums under water sprays or by water from a hose. Neither method is as effective as is desirable. The shells should be cleaned thoroughly so that contamination from them will not be introduced into the meat and juice. After washing, the clams are steamed in crates and retorts similar to those used for oysters. In the west, a combination washer and scalder is used. As the clams die, the shells open and the juice is collected in the retort or steamer. As juice is sometimes used for covering the clams in the cans the most sanitary methods of handling the shell stock are essential. The clam meats are packed at once into cans, covered with fresh brine or clam juice, and processed under steam pressure.

All packing equipment should be of not readily corrodible metal. Perforated utensils should be smooth; wire mesh should not be used.

To prevent contamination of the packing room, shucking must be done in a separate room. Only personnel directly employed in packing should be permitted in the packing room. The packing plant walls and floors should be of impervious material and so constructed that the rooms may be easily hosed down. If the plant is operated during insect season, all exterior openings to the rooms must be screened and the premises sprayed with a suitable insecticide when required. Toilet and washing facilities for employees based on the ratios given on page 43 are satisfactory.

The water supply should meet the requirements for drinking water.

Persons working in the plant should wear aprons or coats which can be laundered and should be trained to wash their hands after use of the toilet. Since the food is handled by the personnel it is of vital importance that no one with exposed sores or a communicable disease be permitted to work. Daily observation of all employees helps to prevent contamination of the shucked shell-fish with infectious organisms.

Shucking stands, pails, and other packing equipment should be kept clean. Pails should be rinsed before each filling. All floors, walls, and benches must be washed free of mud immediately after operations cease each day. Utensils should be washed and subjected to a bactericidal treatment each day. This may consist of exposure to steam, immersion in hot water for 2 minutes, dipping in a chlorine solution having a strength of 100 ppm., or use of a satisfactory quaternary ammonium solution.

Shells from which meats have been removed must be disposed of promptly. This is usually done by dropping them through chutes in the floor into collection bins below.

Shucked shell-fish should be packed in either single service containers of impervious material (waxed paper or glass) or in sealed returnable metallic containers. The packer's certificate number should be embossed upon each unit shipped. Shucked shell-fish must be cooled to below 50° F. within 2 hours and kept at this temperature until consumed.

## CANNING

All of the common foods are canned. Fruits, vegetables, meat and meat products, poultry, fish, shellfish, milk and coffee are readily obtainable in cans or glass containers.

The use of private formulae and secret trade practices in this industry prevailed for many years and seriously impeded its technical progress. Extensive laboratory investigations were found necessary, however, in order to pack products of uniform quality which would not spoil. Hit-and-miss methods could not succeed in such a rapidly developing industry

and were gradually superseded by scientific laboratory control, until commercial canning is today an outstanding example of the profitable application of the results of research to industry.

Cans as commonly used are coated on the inside with tin, lacquers, or enamels. Suitable coatings are used for different products. A satisfactory coating will not injure the flavor or palatability of the product. The "open top" or sanitary can is in general use with the tops crimped to the sides by special machines. This type of can has fewer losses in "swells" and "springers" and is more easily processed. Glass containers have become a natural substitute for tin cans in the packing of foods. In 1942 it was estimated that fruits and vegetables packed in glass amounted to 31 million cans or 11 percent of the total. Plastic containers have not yet been found suitable to replace glass or metal in canning.

## Procedure

Spoilage quickly develops in raw material after picking or cutting from the plant or tree. In addition to the ever present micro-organisms, both fruits and vegetables contain enzymes or chemical ferments. These play a useful role in plant metabolism but may produce destructive or undesirable effects upon the fruit or vegetable as soon as it is removed from the plant. The entire canning procedure should be speedily carried out, to avoid loss of sugars and flavor, as well as to prevent putrefactive decomposition.

Produce received at the cannery is thoroughly washed and sometimes otherwise cleaned. Since practically all the contamination is on the surface of the fruits or vegetables, thorough and effective washing is one of the most important steps in canning. The spray type of washer, in which small streams of water strike the vegetables with considerable force, is generally the best.

Washing should be done either in tanks in which the water is continually replenished, or frequently changed, or, preferably, under a power-spray system of continuous operation. Apples, apricots, pears, cherries, and plums (tree fruits maturing ordinarily some distance from the soil), as a rule should be washed before treatment. Peaches are usually peeled and then washed, while pineapples are cored and trimmed before washing. Soaking in cold water and subsequent brushing of beets, carrots, sweet potatoes, etc., which may have much adhering soil, are necessary. An abundant supply of pure water is essential; otherwise washing may increase rather than remove contamination. A good rule is to regard only water which is safe for drinking as fit for washing in the cannery.

Peaches were formerly peeled by hand, but now this is generally done by

soaking them in a weak, hot lye solution (about 2 percent sodium hydroxide). After the lye treatment, the fruit should be well brushed and thoroughly rinsed to insure effective and complete removal of the solution. Grapefruit is scalded and then peeled by hand. The peeled fruit may then be given a short lye bath to remove the "rag", after which the fruit is thoroughly brushed and washed. Apples are generally peeled by machine. The sprockets holding the apples, the peeling knives, and the conveyors should be thoroughly flushed with water, in order to remove dirt and bits of fermenting fruit.

After washing and peeling, the fruit should be inspected and the imperfect or partly decayed fruit sorted out. Bruised or slightly imperfect fruit may be trimmed for a low-grade pack or for jam or jelly. Peeling or cutting vegetables is usually done by machinery, although peas and lima beans are removed from the pods by "viners", machines in which the pods are broken open by striking them against baffle boards.

At some stage in the preparation of vegetables for canning, the materials should pass before inspectors where objectionable particles are removed or trimmed away. During the rush season in a cannery there is a tendency to crowd the prepared vegetable conveyors or to speed them up, so that inadequate inspection results. This should be avoided, since the quality of the finished product is largely dependent upon adequate inspection.

Packing of fruits and vegetables into cans or glass containers is usually done by hand. This is the only way to avoid slack or over-filled cans and prevent use of broken or cut material. Mechanical fillers are utilized to add brine to vegetables or syrup to fruits to give the desired weight.

Women and girls are generally employed for packing peaches, apricots, grapefruits, pears, and pineapples into cans. Because of the deftness required in such work they are physically better suited to it than are men. Close supervision of the health, clothes, and personal habits of the workers is essential. The use of caps, aprons, and, in some cases, gloves is urgently recommended, but such equipment should be kept scrupulously clean. The hands of packers must be inspected frequently as certain fruit juices contain active enzymes which quickly cause sores. Persons who are especially susceptible to such action, should not be allowed to handle the prepared fruit.

Vegetables are generally blanched, that is, immersed in hot water (scalding or almost boiling temperature) for from one-half to two minutes. This not only further reduces contamination, but also removes gelatinous substances, softens the texture to facilitate filling the cans, and provides a short pre-cook, which is advantageous in fixing color and arresting or re-

tarding enzymic action. The blanch water must be kept clean and at the predetermined temperature; otherwise the operation does more harm than good. Foul blanching water is a weak spot in a cannery, is unsafe and a source of heavy bacterial contamination.

Filled cans are passed through an exhaust box, made preferably of stainless steel for ease of cleaning, by a belt conveyor. This box is essentially a hot water chest or steam holder, and the temperature of the products in it is raised to about 130° F. which removes entrapped air by expansion. The can is then sealed and processed; that is the contents are heated sufficiently to prevent spoilage. The contents are not necessarily sterilized but are heated sufficiently to retard bacterial growth and spore vegetation. Sterilization is not practicable; it would make the products unmarketable because of poor appearance. Process temperatures, however, destroy all pathogenic organisms.

The heating temperature and holding time vary for each food. Processing is accomplished in an autoclave filled with hot water or steam, usually in separate batches. After processing, cans are immediately cooled with running water to prevent overheating and thermophilic spoilage when stacked. Thermophilic organisms have optimum growth at 130° F. These contaminants come from the raw products, added ingredients, or dirty equipment.

Fruits in tin or glass containers are processed at temperatures not above 212° F. This is usually sufficient to prevent spoilage. The acidity of most fruits increases the effectiveness of the heat treatment in killing the contaminating micro-organisms, and also provides conditions in the finished canned product unfavorable for development of the bacterial spores or thermophilic (heat-resistant) micro-organisms which have survived the processing. As fruit flavors, especially the more delicate ones, are easily impaired by heat, the processing should be maintained at a safe minimum temperature.

Vegetables, as a rule, pack more densely into the cans than do fruits, so that the rate of heat penetration in the sterilization process is much slower. For this and other reasons, higher temperature and longer processing time are necessary in canning vegetables. Furthermore, in the absence of the preservative action of the acids found in fruits, it is necessary almost to sterilize the vegetables since residual bacterial spores may otherwise develop during storage.

Fruit and vegetable juices are now packed with better retention of flavor due to the use of flash pasteurization combined with deaeration for processing. Temperatures in the "high-short" method are usually in the 250–300° F. range and the treatment time is a matter of seconds to a few minutes.

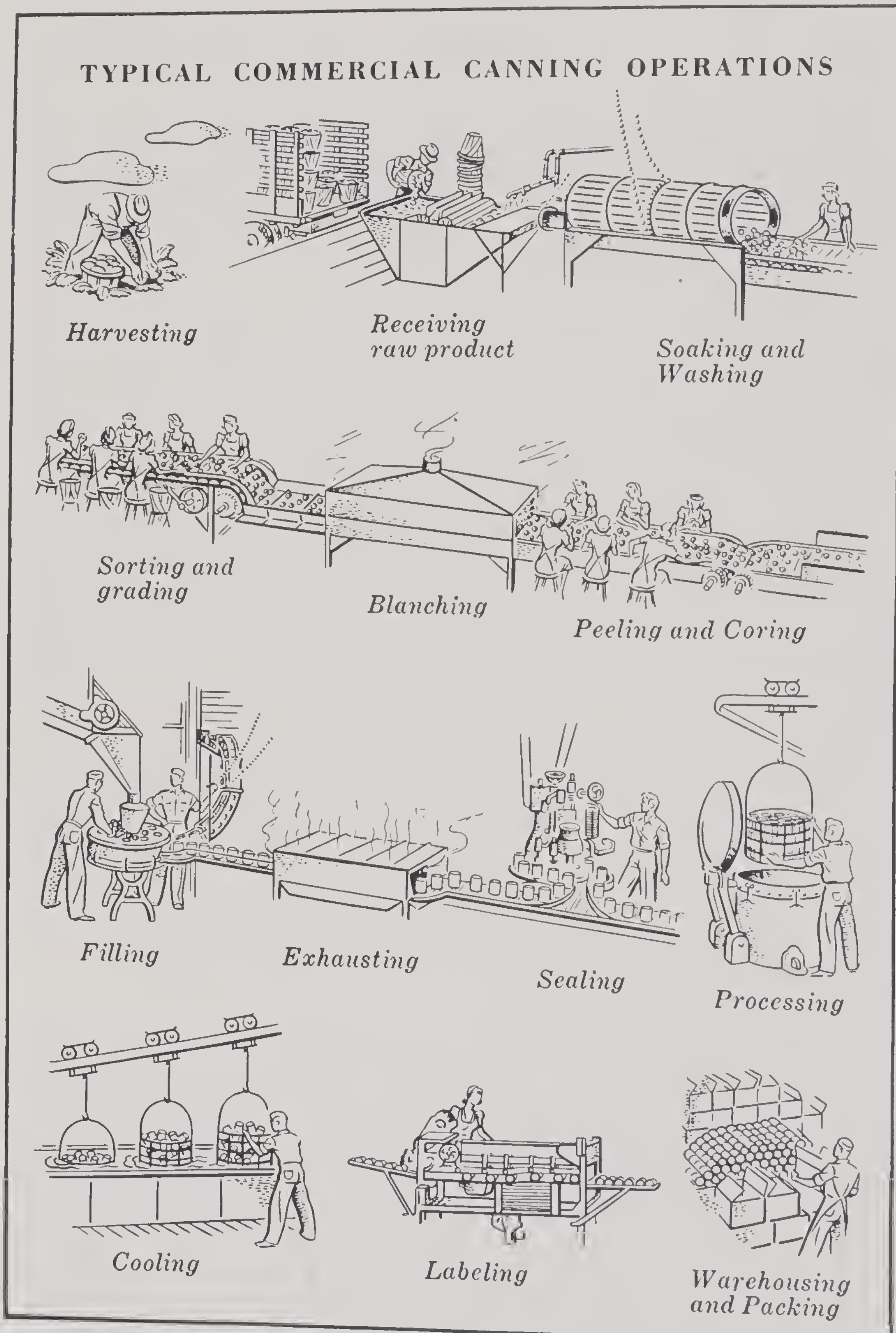


FIG. 8. Typical Commercial canning operations. (Courtesy, American Can Co.)

## Spoilage

Even with the most meticulous care in preparing and canning foods by the commonly accepted methods, a certain percentage of spoilage of the canned goods is to be expected. This is due to the fact that the processing temperature and pressures are compromises between a point high enough to insure complete sterility, and a consequent impairment of aroma, flavor and other factors of high quality, and temperatures and pressures so low they fail to preserve the product.

Spoilage in canned goods is usually indicated by a condition of the can called "hard swell" or "flipper." Either condition is caused by pressure in the can produced by bacterial action. The ends of normal cans are concave, or if convex, when outside pressure is applied, the concave shape results and remains. If pressure develops inside the can one or both ends will be forced into a convex shape. The pressure in a hard swell is such that both ends are bulged out and cannot be pushed into a concave position by outside pressure. The flipper is characterized by sufficient pressure to cause one end to bulge. If the bulged end is pushed in the other end is pushed out. Either condition is cause for rejection of the contents. In addition, any can that shows any leakage should be rejected. Still another condition demanding rejection is that of the flat sour. The cans do not show bulged ends, but the contents on being opened or heated, give off an abnormal sour odor.

Spoilage of canned fruits may result from the growth of yeasts or bacteria which have survived the cooking process for various reasons, such as inadequate sterilization, errors in processing, or imperfect sealing which may permit micro-organisms to gain entrance to the can after processing. In any event, if viable micro-organisms are present, fermentation of the sugar will occur with the production of gas (mostly carbon dioxide and hydrogen), which soon develops sufficient pressure to bulge the ends of the cans, producing "hard swells".

In addition to the possibility of extensive spoilage in vegetables inadequately processed resulting in serious financial loss to the canner, there is also the danger of food poisoning from the growth of *Clostridium botulinum*. Spores of this micro-organism are widely distributed in the soil and are considered to be potentially present on all raw vegetables. This micro-organism produces a very poisonous toxin which fortunately is completely destroyed by the heat employed in cooking canned vegetables in the home. All non-acid vegetables, therefore, should be processed commercially under steam pressure sufficiently high to kill the *Cl. botulinum* spores. Commercial canners are aware of this danger, and it is a compliment to their efficiency that no outbreak of food poisoning from this organism

in commercially canned vegetables has occurred in recent years. However, the possibility of this danger is ever present.

## Cleaning

At noon and at night, in fact before any extended shut-down period of the factory, all equipment actually handling the fruit or other ingredients should be thoroughly cleaned. Pipe lines and equipment not readily accessible should be flushed out and steamed. Good personnel must be chosen for cleaning tasks. Slip-shod or poorly supervised work must not be tolerated. Equipment must be kept clean to prevent the growth of organisms even when used with acid products such as tomatoes or pineapples. Growth spots for bacteria, particularly thermophiles, are blanchers, blenders, brine tanks and lines, fillers, flumes, mixers and hot water pipes. The bacteria may be eliminated by flooding the equipment with cold water for 24 hours *while it is kept in continuous operation.*

Sterilization and normal processing temperatures are not to be substituted for the selection of good raw material and cleanliness in the factory.

Handling of the materials, packing, processing, coding the containers, and, in fact, the entire canning operation should be carefully and efficiently conducted and supervised. The processor of any food accepts a grave responsibility. The canning industry is meeting its responsibilities to the public and "canned foods whether prepared in the home or in commercial canneries regardless of the type of container, are sound, wholesome and safe."[8] Botulism in home canned products is, however, a hazard of improper methods.

Adequate and convenient lavatories for each sex must be provided. An accepted rate of facilities for personnel is:

| | |
|---|---|
| Drinking fountains | 1 per 75 employees |
| Washing facilities | 1 per 10 employees |
| Water Closets* | 1 for 1–9 persons |
| | 2 " 10–24 " |
| | 3 " 25–49 " |
| | 5 " 50–100 " and |
| | 1 for each additional 30 persons over 100 |

* Urinals may be substituted for water closets up to $\frac{1}{3}$ the total installations for the male section.

Disposal of wastes from canneries always presents a complex problem. Quantities of wastes are usually large and frequently confined to only a few weeks of the year, making disposal facilities unusually expensive. In many instances discharge of the canning wastes into a municipal sewerage

system will overload the treatment facilities or disrupt treatment methods. Solution of the waste disposal problem is one for competent, trained engineers.

## REFRIGERATION

The commercial preservation of foods by low temperature is known as refrigeration. In many respects it is complementary to the preservation of food by heat. It was an obvious development in regions where natural ice was available for at least a part of the year, and with the introduction of artificial ice it became universal. Meat packing and the distribution of perishable food could not have reached their present great economic importance without artificial refrigeration. Commercial refrigeration has changed the dietary habits of people throughout the world.

The first practical device for freezing and cold storage of fish was invented by Enoch Piper of Camden, Maine, who obtained a patent in 1861. The first cargo of frozen meat received in England was shipped from Melbourne, Australia, in 1873.

Refrigeration may be divided into two types: storage, which, in this discussion, is the refrigeration of foods at temperatures just above 32° F., and "freezing" which refers to refrigeration at temperatures well below this temperature.

### Cold Storage

Cold storage warehouse temperatures vary from 0° to 40° F. depending upon the food being held. Cold storage procedures are utilized to extend the short natural season of foods throughout the year. It is not profitable to keep food in storage after the second season and many state laws prohibit this practice.

While refrigeration is now indispensable to the food producer and distributor and of tremendous importance to the consumer, it has introduced many problems in sanitation and public health in the preparation and handling of foods, both in the factory and in the home.

Foods may enter cold storage rather seriously contaminated with microorganisms, so that great care must be exercised to prevent spoilage. Relative humidity is very important in the refrigeration of foods. Too high a relative humidity permits or stimulates the growth of molds, and too low a relative humidity leads to the dehydration of the food until it may become practically inedible. Fruit, vegetables, eggs, cheese, butter, lard, and meat are kept at 85 percent relative humidity with dried products at about 50 percent. Maintenance of these conditions requires ventilation and air movement. Furthermore, since many bacteria, yeasts, and molds grow at temperatures just above freezing, and enzymic and chemical changes

slowly progress at low temperatures, the length of time such products can be retained satisfactorily and profitably under cold storage conditions is limited.

The apple is the principal fruit held in cold storage, although other fruits, such as pears and plums, are also held successfully. Although usually contaminated with micro-organisms, the relatively thick skin of the apple is covered naturally with a protective waxy coating, and spoilage is generally confined to areas surrounding abrasions or bruises in the skin and tissue beneath. To withstand long commercial storage, the best apples (in some cases wrapped in paper) are hand packed into strong, clean baskets or boxes. Since the containers remain unopened during storage, the only protection against spoilage is the maintenance of the proper temperature and relative humidity within the storage rooms. This fact makes it imperative that the apples shall be clean when packed. Residues of insecticides sprayed on the fruit during growth should be removed before packing. This frequently requires washing in water or weak detergent solutions, brushing, and drying.

Practically all fruits absorb strong foreign odors in cold storage and many fruits also give off relatively strong pungent odors. For this reason fruits in storage should be isolated from other food products. In fact different types of fruit should be stored separately.

Fruit mixed with sugar has been commercially preserved by cold storage since 1910. Berries, peaches, pineapples, and cherries are the fruits most commonly preserved in this way. Such fruits, usually packed in barrels or other large containers, are used in the manufacture of jams and jellies, ice cream, candies, pies, etc.

Berries should be carefully picked over or inspected. The marks left by insects may be very small, although the eggs, larvae, or even the insects themselves may be inside the fruit. Mechanical methods have been developed for some of this sorting. Berries are particularly susceptible to decomposition during handling. The fruits are delicate and easily injured, and once the skin has been broken fermentation proceeds rapidly. Any type of incipient spoilage is more serious in fruit for freezing than in fruit for canning or preserving.

Berries and cherries are naturally contaminated with yeast, molds, bacteria, insects, and often with filth. Very careful washing is essential to remove all traces of objectionable matter. There can be no aesthetic tolerance and there should be no legal tolerance for the cold packing of decomposed, dirty or insect-infested fruits.

The temperature used for freezing and the type and size of container are the most important factors in the freezing of cold-packed fruits. As a temperature of approximately 40° F. is generally considered necessary to

inhibit fermentation, most products should be completely cooled below that temperature within as short a time after packing as possible. Microbial activity will continue slowly even if cooled below 13° F., yeasts and molds having been found to increase at 20° F. Methods for pre-cooling the pack or the use of small containers to insure rapid cooling is therefore desirable.

Several kinds of fresh vegetables may be held under refrigeration for short periods of time. Although low temperatures are used to delay spoilage, this practice does not permit long holding and, therefore, is not included here as an instance of the cold storage of foods. The potato is the principal vegetable which may be placed in cold storage for several months with commercial profit. Bags or barrels of them are delivered to the cold storage warehouse and usually are not opened during storage. As they do not spoil readily, maintenance of the proper temperature and relative humidity during storage is generally sufficient.

Although vegetables which have been in contact with the soil are considered as potentially carrying the spores of *Clostridium botulinum*, care in packing clean, properly prepared, sound products and in maintaining them in a frozen condition precludes serious danger of botulism.

The proper preservation of shell eggs by refrigeration has made satisfactory eggs available in the urban centers throughout the year, and has resulted in a marked increase in their consumption. Although eggs are not frozen in storage, bacterial deterioration is prevented or greatly retarded. However, as enzymic breakdown and shrinkage (i.e., loss of water accompanied by shrinkage of the egg white and enlargement of the air cell) do occur, after several months of storage most eggs show unmistakable signs of deterioration. A high relative humidity in the storage rooms reduces shrinkage, but often promotes the growth of molds on the shells and wooden cases.

The breakdown of the egg apparently is brought about by an enzymic action on the white or high protein portion. This activity is facilitated by development of an increased alkalinity, approaching a pH of 8.5 as the optimum for its activity. The increased alkalinity of the egg white is due to a continued loss of carbon doixide normally present in the egg. The natural carbonic acid content of the eggs may be maintained by two methods: by providing a small amount of the gas in the atmosphere of egg storage rooms or by sealing the pores of the shells with a thin oil which may or may not be saturated with it. Both methods considerably reduce the enzymic deterioration of eggs in storage. The oil method has the added advantage of retarding the loss of carbon dioxide gas after the eggs are removed from storage.

Egg shells are very porous, and eggs quickly absorb foreign odors. These

TABLE 1

*Storage Conditions and Properties of Some Perishable Products*

| Product | Range of Storage Temp. °F. Over 2 Weeks Warehouse | Optimum Humidity Percent Forced Air Circulation | Freezing Point °F. | Maximum Storage Period |
|---|---|---|---|---|
| Fruits | | | | |
| *Apples | 30–32 | 88 | 28.5 | 8 Months |
| *Bananas | 55–56 | 80 | 26–30 | 10 Days |
| Berries | 31–33 | 85 | 26–29 | 7 to 20 Days |
| Cantaloupe | 50–55 | 85 | 30.5 | 20 Days |
| *Grapefruit | 32–34 | 90 | 28.5 | 90 Days |
| *Lemons | 50–55 | 85 | 28 | 90 Days |
| *Oranges | 32–34 | 85 | 28 | 2 Months |
| Peaches | 31–33 | 85 | 29.5 | 30 Days |
| Pineapples | 38–40 | 85 | 28 | 30 Days |
| Vegetables | | | | |
| Asparagus | 32–34 | 90 | 30 | 30 Days |
| Beans (string) | 32–34 | 90 | 30 | 30 Days |
| Beets | 32–34 | 90 | 27 | 7 to 90 Days |
| Cabbage | 32–34 | 95 | 31 | 4 Months |
| Celery | 31–33 | 90 | 30 | 2 to 4 Months |
| Cucumbers | 50–60 | 85 | 30.5 | 10 Days |
| Onions | 32–34 | 75 | 30 | 5 to 6 Months |
| Potatoes | 38–42 | 90 | 29 | 6 Months |
| Tomatoes | 50–55 | 85 | 30.5 | 10 Days |
| Meats | | | | |
| Bacon | 28–30 | 85 | — | 15 Days |
| Beef (fresh) | 30–32 | 87 | 27 | 3 Weeks |
| Hams & loins | 28–30 | 85 | 27 | 3 Weeks |
| Livers | 20–22 | 80 | 29 | 6 Months |
| Pork (fresh) | 30–32 | 85 | 28 | 15 Days |
| Poultry (frozen) | 0–5 | 85 | 27 | 10 Months |
| Sausage (smoked) | 32–40 | 80 | 25 | 6 Months |
| Veal | 28–30 | 87 | 29 | 15 Days |
| Miscellaneous | | | | |
| **Beer (wood kegs) | 34–38 | 85 | 28 | 6 Months |
| ***Beer (steel kegs) | 34–38 | 70 | 28 | 6 Months |
| Butter | 15 | 80 | 30–0 | 6 Months |
| Cheese (American) | 32–34 | 80 | 17 | 15 Months |
| Cheese (Swiss) | 38–42 | 80 | 15 | 60 Days |
| Eggs (frozen) | 0–5 | 60 | 27 | 18 Months |
| Lard | 32–34 | 80 | — | 6 Months |
| Milk | 35–40 | 70 | 31 | 5 Days |
| Oleo | 34–36 | 80 | — | 90 Days |

* These items and other fruits which give off carbon dioxide in appreciable quantities require ventilation at the rate of four to six air changes per 24 hours.

** Wooden beer kegs weigh 66 lbs. each and have a specific heat of 0.50.

*** Steel beer kegs weigh 45 lbs. each and have a specific heat of 0.10.

may arise from other food products in the same warehouse room or, what is much more objectionable, from dirty cases or packing materials which have become soiled from broken or dirty eggs. Eggs in storage give off considerable odor, making proper methods of forced ventilation desirable. The floors and equipment in the storage rooms should be kept clean. The walls and ceiling should be painted or whitewashed before the eggs are stored. Water should be kept off the floor, walls, and ceiling, and careful control of both relative humidity and temperature must be maintained at all times.

Cold storage plants should be periodically cleaned prior to packing with food. This may be accomplished by sweeping but if floor drains are provided the walls and floor should be hosed. Catch basins should be installed to keep debris from clogging the sewer. Since the number of persons required to operate a plant is small, normally one well equipped lavatory is satisfactory.

## Quick Freezing

For many years the only method of freezing foods (as distinct from cold storage) was to hold them in rooms maintained below 32° F., generally from 0° to 15° F. Modern methods have changed this considerably.

About 5 million pounds of food are frozen in the United States annually.[9] There are at least 20 "quick freeze" processes in use. Basically these consist of immersion in liquids, gas and air, or plate surface contact. In these processes fresh foods are packed into containers, immediately frozen in not more than 30 minutes, and subsequently delivered to the consumer in the original package. In the original Birdseye process cold brine was sprayed on the outside of a conveyor belt freezing the food carried on it. In a later modification, food is placed on plates stacked in a frame through which ammonia is circulated in an expansion system. Cold air blasts, direct spraying with brine, and passage through a pre-cooled tunnel are other methods. The plate or surface type is the most popular giving the greatest freezing per unit area with lowest maintenance costs.

Freezing is accomplished between −10° F. and −30° F., and depending upon the process used, may be either a batch or continuous process. Meats, fish, vegetables, fruits, fruit juices, shell fish, and pre-cooked food are now quick frozen and commercially available. For individual package freezing a gas tight, moisture proof, cellophane paper is essential to prevent dehydration.

Vegetables selected for "freezing" or "cold pack" are prepared in much the same way as for canning. In fact, the entire preparation and packing may be carried out satisfactorily and efficiently in a cannery, if the sealed containers are put in freezing storage immediately. Washing, trimming,

and sorting should be done in the shortest time possible. Delay may impair the quality, especially if there is also delay in freezing, as in the slow freezing process. Unlike fruits, which contain considerable sugar and acid and are likely to undergo fermentation by yeasts, vegetables contain little or no sugar and acid but are more subject to decomposition by bacteria.

As a rule, the vegetables are packed into containers by hand. Before freezing, they are usually blanched in scalding water or steam. Vegetables


FIG. 9. Retail sanitary frozen food display cabinet, Baltimore, Md. (Courtesy, Wagner's Food Stores.)

should be packed and frozen immediately after blanching. Delays mean incipient microbial spoilage. Frozen fruits, vegetables, and meats are held at 0° F. and retain their natural flavors for at least 6 months. A bacterial standard of 100,000 organisms per gram after 72 hours incubation at 37° C. with absence of *E. coli* has been proposed. Good sanitation and cleanliness in the plant will remove any danger of botulism. A water supply comparable in purity to that required for drinking water is necessary, particularly when brine sprays or immersion procedures are used.

The packaging and processing departments must be kept scrupulously clean. Equipment and floors must be hosed down, utensils cleaned and sterilized with steam or in chlorine water or other bactericidal agent, and

hot water must be available for scrubbing tables and walls. Freezing belts and plates must be inspected and cleaned after use each day since contamination from spilled packaged goods is unavoidable.

The retail display cabinet is an important factor since it is *not* under the direct supervision of the quick freeze processor. The local merchant must be trained to keep it clean, defrost it at stated intervals and be educated to realize that only by so doing will high quality products be satisfactory to customers.

As defrosted cold-packed fruits are more susceptible to fermentation than are fresh fruits, these materials should be maintained in a continuously frozen condition, not only during storage but also during transportation, in the retail store, and in the home until just before consumption.

Although properly controlled refrigeration preserves foods satisfactorily for months, and solid freezing preserves some products for years, foods are very susceptible to spoilage when removed from refrigeration. This is in marked contrast to the commercial preservation of foods by heat, since in canning the major causes of decomposition, namely, micro-organisms and enzymes, are inactivated by the sterilization process. Foods removed from refrigeration are as a rule highly perishable, and this should be kept in mind in all handling.

## Food Lockers

Food locker freezers were developed about 1900 when cold storage plants furnished space for private use in the chill rooms. Later, freezing sections were added. The first modern type locker plant was installed in 1913.

The installations freeze food and hold it in storage for individual use. They supply steel compartments varying from $4\frac{1}{2}$ to 25 cubic feet capacity in large freezer rooms kept at 0° F. with the relative humidity between 80 and 85 percent. The compartments are rented to persons and provide for direct access to the contents. In addition, quick freezing facilities are available upon a fee basis and the plants are equipped for the cutting, preparing, wrapping, and packaging of meats, fruits, and vegetables. A cellophane type of paper is used to retard dehydration.

The preparation and locker rooms must be constructed of impervious materials, be furnished with a supply of hot and cold water, and be well ventilated and lighted. Forced ventilation is generally used in the locker room. Equipment and rooms must be cleaned daily. Since compartments are private, only general supervision of their cleanliness may be required of the plant operator. Normally one well equipped lavatory for each sex is sufficient for sanitary requirements.

The following major items should be considered in planning the construction of a food locker plant: preparation of plans by competent engi-

neers; proper use of low heat conductance material; uniform compressor facilities; and standby electric service.[19]

### Preserving

This term as applied to the preservation of food is usually restricted to a process of partial cooking with sugar. Most preserves, jams, and jellies are fruit products, although a few vegetables are preserved. Fresh fruit and frozen fruit either with or without sugar are the materials used by the jam maker. The observance of all of the precautions listed under the section on canning of fruits and vegetables is quite as applicable here. Over-ripe fruit or fruit which is partially fermented will not yield a product of good texture and satisfactory flavor. The high temperature at which jams, jellies, and preserves are cooked usually assures the destruction of micro-organisms. It is advisable to transfer the hot material at once to the retail packages and quickly seal them. The preserver, like the canner, should realize that he is dealing with a highly perishable product and that only by careful control of the cleanliness of his factory can he expect to produce a sanitary product.

### Pickling

The preservation of foods by pickling is an important industry in the United States. Cucumbers, cabbage, onions, peppers, cauliflower and green tomatoes are the principal products prepared in this manner.

Cucumbers, the most important of the pickles, are finished as sweet, sour, or dill pickles. During rainy seasons, cucumbers may arrive at the pickling stations covered with earth. There is a difference of opinion among operators as to whether cucumbers should be washed before salting, since washing affects the subsequent fermentation and cure, as the naturally adhering micro-organisms are responsible for the fermentation.

Cucumbers are usually graded for size by machinery and then dumped into large vats and immediately covered with a brine of from 8 to 15 per cent concentration of salt. Fermentation develops rapidly and some lactic acid is produced which is believed to influence the quality of the product. In some plants the pickling vats, holding in some cases 1,000 bushels of green cucumbers, are located outside the plant and are left uncovered. This practice permits the weakening of the brine by rain, and unless the brine is frequently checked and more salt added, the strength may be reduced to a point where the cucumbers will soften and rot. If the vats are covered, however, the absence of sunlight permits the development of *Mycoderma*, which may destroy the acidity of the brine and lead to serious decomposition of the cucumbers. Covered vats must be skimmed frequently during the fermentation and storage periods. The fully fermented cucumbers are then

ready for final manufacture into sour or sweet pickles or pickle products. The fermented stock is soaked to remove the excess salt and then thoroughly washed and, if necessary, brushed to remove adhering grit. The stock next goes to the pickling vats where the hot or cold vinegar, spices, etc., are added and, in some processes, a mild cooking is given but not sufficient to soften the finished product. To produce a satisfactory quality of product the same care must be exercised in the control of pickling operations as in canning.

Onions, peppers, cauliflower, and green tomatoes are pickled in a brine containing at least 15 percent sodium chloride. Although a short fermentaion may occur, it is not a vital part of the curing process. However, if the vats are located indoors, *Mycoderma* will grow upon the surface of strong brines, and must be regularly skimmed off. Provision for disposal of the scum should be provided, and the plant kept scrupulously clean. Otherwise, the quality of the finished product will be impaired.

Cabbage is manufactured into sauerkraut by a fermentative and curing process, which is controlled largely by added salt (sodium chloride). Cabbage is relatively resistant to deterioration for a few days after harvesting, allowing ample opportunity for delivery to the factory, shredding, and packing into vats before serious deterioration begins. Worm-eaten areas should be carefully trimmed away along with the outer leaves.

The shredded cabbage is uniformly salted and packed solidly into vats to avoid unsalted areas and pits where deterioration may take place. Every precaution should be taken to ensure proper initial salting, as further salting of the full and headed vats is not practicable. The vats should be under cover and within a screened enclosure to avoid dilution of the brine by rain and to prevent contamination by insects.

Because of its relatively high acidity, cabbage sauerkraut is readily preserved in cans by a short pasteurization.

## BAKERY AND CONFECTIONARY PRODUCTS

In the United States before 1850, bread was produced primarily in the home, whereas today the baking industry, a billion dollar business, supplies most needs.

Bread, rolls, cakes, cookies, crackers, and pies are the major bakery products. The sanitary aspects of their manufacture may be considered under three headings: the sanitary condition of the ingredients, the necessary sanitary precautions in the manufacturing processes in the bakery, and the sanitary precautions used in handling the finished products in distribution.

Flour, sugar, salt, dried or frozen eggs, spices, raisins, and other fruits

should be clean and wholesome when received at the bakery, and during any holding period they should be protected from insects, rodents, and other sources of contamination. Every properly equipped bakery must have ample refrigeration space for the storage of fresh and frozen eggs and other perishable materials, such as pie fillings. In the manufacturing operations rigid principles of sanitation should be strictly enforced. For example, doughs should be set to rise (by yeast fermentation) in air conditioned rooms, and cake frostings and cake and pie fillings should be protected from flies and other insects. Frozen eggs should be defrosted only as needed and used immediately. Pans and utensils should be cleaned and thoroughly dried immediately after use. The entire bakery should be well screened, well lighted, and thoroughly protected from the accumulation of waste products and from outside odors.

"Ropiness" in bread often indicates lack of sanitation. "Ropiness" is an area of soft and sticky dough within a loaf of bread, caused by the growth of spoilage bacteria of the *Bacillus mesenterious* group. The spores of this micro-organism are widely distributed in the soil, and frequently may be isolated from flour. A general contamination of the walls, floors, and equipment of a bakery with the spores of this micro-organism will lead to serious contamination, impairing the quality and, if uncontrolled, resulting in almost certain spoilage of the bread. The addition of very small amounts of sodium propinate in the wrapper will inhibit mold growth.

The walls of a baking room should be washed frequently and, unless they are finished with tile, frequently repainted. The building should be rat proofed and kept free from insects.

The precautions necessary for the sanitary handling of bakery products mean much to the profits of the baker, and they mean much to the health of the consumer. Many bakery products are highly susceptible to decomposition, certain types of which may cause serious cases of food poisoning. Frostings, fillings of cakes, pies and tarts, rich pastries, etc., offer favorable conditions for bacterial spoilage. So much publicity is usually given to cases of food poisoning resulting from the consumption of commercially prepared food that some bakers refuse to manufacture such highly perishable articles as cream puffs and similar custard pastries during the summer. In many instances this policy was established by request of local health authorities.

The sanitary handling of bakery products during transportation and in the retail store has improved notably in recent years. The wrapping of bread, cake, and pastries with paper or cellophane has added greatly to cleanliness and safety in the dispensing of these products and should be required by state, county, or city ordinance.

Use of vacuum cleaners instead of brooms during cleaning operations will pay sanitation dividends by keeping down dust and its attendant bacterial contamination.

The baker and retailer of bakery products must be trained to realize that the nature of the product and the method of consumption place upon him an obligation greater than the dispenser of other types of food, since his product is ordinarily eaten "out of hand," that is, consumed as received, without additional cooking.

FIG. 10. Retail sanitary bakery display, Newark, N. J. (Courtesy, Dugan Brothers, Photograph by Halsey Douglas.)

## BOTTLING

Large quantities of non-alcoholic, still and carbonated beverages are manufactured each year. The quality of all raw materials, and the care and cleanliness of the equipment and of the bottles used, determine not only the wholesomeness but, in a large measure, the keeping quality of the finished beverage.

Water is the basic ingredient of these products, and its sanitary condition should be equal to the best drinking water. Some bottlers take the precaution of distilling all water used. A small amount of mineral matter in

solution which would be permissible in drinking water, may lead to clouding and precipitation in bottled beverages. Such impurities usually must be removed by water softeners or by chemical purification.

Bottled carbonated beverages and imitation fruit juices contain sugar and often citric or other organic acid, coloring matter, and carbonic acid. Solutions of flavoring materials which contain a fruit base are susceptible to spoilage; consequently only such quantities should be prepared as can

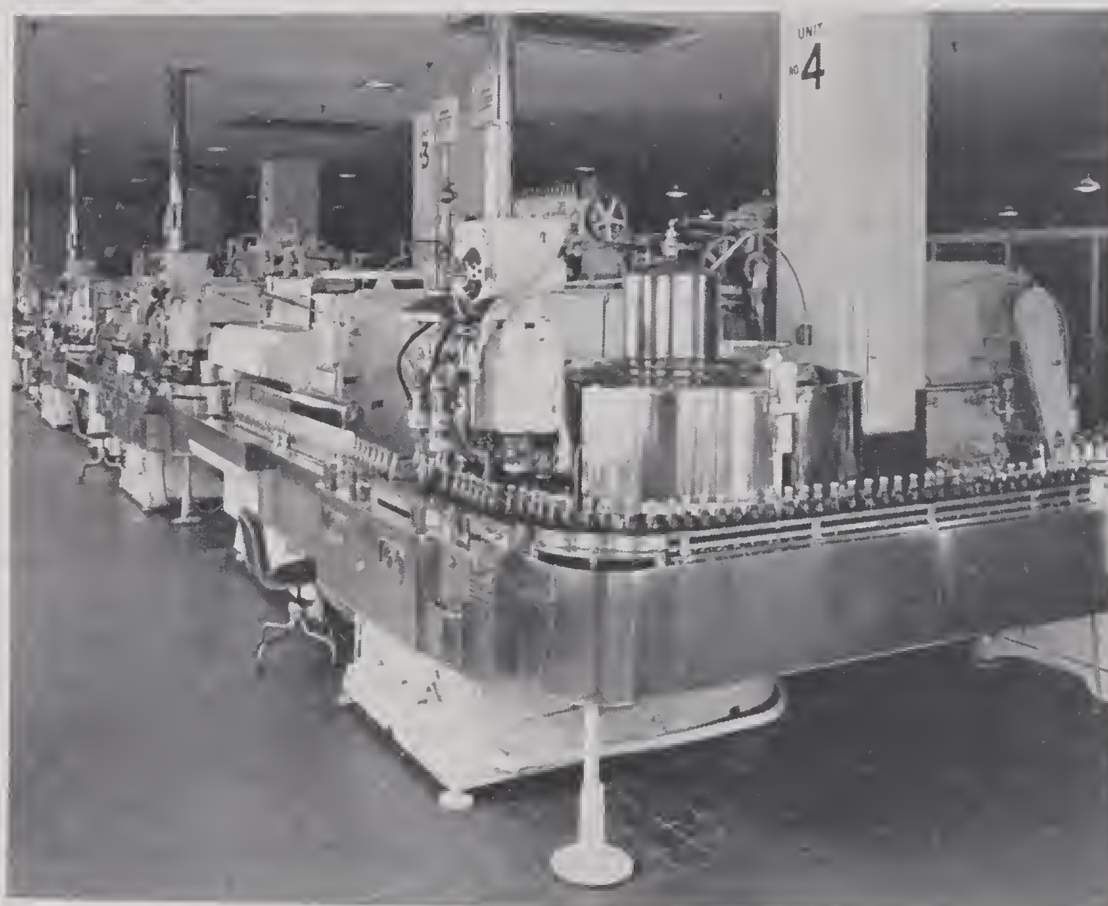


FIG. 11. Bottling carbonated beverages. (Courtesy, Coca Cola Bottling Co., Photograph by Mettee Studio.)

be quickly utilized. The growth of yeast, bacteria, or molds in solutions of coloring or flavoring materials usually leads to serious contamination of bottled beverages, and often to spoilage. The syrup room, the very heart of a bottling plant, should be kept scrupulously clean and fully screened against flies, and the equipment should be sterilized between batches. Washing in a chlorine solution of 100 ppm. followed by rinsing is an excellent procedure.

Yeast and mold spoilage will occur if bottled beverages are prepared with fermented raw ingredients, if microbial growth has been permitted in pipe lines or other equipment, or if unclean bottles or bottle caps are used. Pathogenic bacteria cannot grow in carbonated beverages, and,

judging by tests on the viability of colon-typhoid bacteria in such bottled products, they are probably killed.

Methods for the proper cleansing of used bottles in soaker type washers followed by a strong spray of hot water have been developed. A mixture of caustic soda and sodium phosphate is considered the best detergent since it cleans and also has germicidal effectiveness. The clean bottles are inspected before and after filling, leaving the bottler to detect foreign particles and to remove cracked bottles. The fact that beverages are consumed practically as prepared at the plant obligates the manufacturer to produce products that are above question in sanitary quality.

## DEHYDRATION

The oldest process of food preservation is drying. The older method of sun drying has generally been replaced by artificial procedures, designated as dehydration. Where climatic conditions provide long rainless periods, and high solar heat, fruits and vegetables are sun dried. Several days are required at temperatures of about 120° F. The fruits especially suitable to this process are apples, apricots, currants, peaches, pears, prunes and grapes.

Sorting on well lighted tables to provide good quality and uniformity is important prior to drying. Apples, pears, peaches and apricots darken upon exposure to air. The discoloration can be prevented by treatment with sulfur dioxide, accomplished by placing the trays of freshly cut fruit in specially constructed "fuming" houses, where it is subjected to the fumes of burning sulphur. The process is carefully controlled to avoid an excess of sulphur dioxide remaining in the finished fruit. This treatment also kills insect infestation. Sun dried fruit is subject to insect infestation and, unless the drying yards are fully protected and carefully patrolled, other objectionable forms of contamination may occur from rats, mice, birds and fowls. In the preparation of foods of which dried fruit is one of the ingredients, a thorough washing of such products as currants and raisins is usually essential.

Forced draft dryers or dehydrators with controlled temperatures are used for artificial drying. The kiln (batch) and tunnel or conveyor (continuous) are the most common forms. A rotary kiln is also used. Air at 165° F., with not more than 25 percent relative humidity, is admitted at velocities between 600 and 1,000 cubic feet per minute. The exhaust air contains about 65 percent humidity and has a temperature of about 135° F. The moisture content of dehydrated fruits and vegetables is held to 5 percent.[5]

Dehydration tunnels are long rooms in which the products are moved forward against a counter current of air. The food is laid on large trays about 3 feet by 6 feet which are stacked on trucks and passed through the

tunnel. The tunnels are about 50 feet long and drying requires from 6 to 8 hours. A similar arrangement is used for the compartment dryer with the air passing from bottom to top.

Vegetables are blanched prior to dehydration to prevent darkening by inhibiting the enzymes present. Leafy vegetables must be placed in the dehydrator within 3 hours after being cut. Tuberous vegetables may be safely held for about a week before drying.

Fruits are marketed in paraffined, paper lined, wooden boxes and individual pastboard cartons. The dried fruit is packed into them under pressure forming a solid block which retards air and moisture penetration. This tends to preserve the contents. Vegetables are packed in consumer size, paper cartons; the contents do not keep well and should be used immediately upon opening.

Dehydrated foods are susceptible to insect infestation. When the moisture content is not over 5 per cent this is reduced to a minimum. Fumigation of stored fruit with methyl bromide at 3 to 4 week intervals is good practice to prevent secondary infestation. Re-heating of dried vegetables to 140° F. for 15 minutes will destroy insect infestation.

Dried and dehydrated foods have not been involved in food poisoning cases of magnitude and it may be concluded that they are relatively free from pathogenic organisms. Bacterial standards are under study and other than to suggest the absence of *E. coli* organisms and pathogens, definite types or plate count density have not been agreed upon.[12]

Sanitation at dehydration establishments is comparable to that in a canning factory. The water supply must meet drinking water standards. Liquid wastes and sewage disposal must be discharged into a public system or a septic tank and tile field. Solid wastes, particularly from vegetable dehydration, are useful as stock for cattle feed.

## ICE MANUFACTURE

Ice is manufactured commercially by the "can" method. Water is placed in large cans which are then immersed in tanks of brine kept at low temperature by refrigeration. Each can forms a 300 pound cake of ice after 36 hours of freezing. A stream of air is bubbled through the freezing water to concentrate the solids into a small volume. These are removed by pumping out the material that collected in the center of each can. The space is filled with clear water just before the cake is completely frozen, giving a crystal clear product for marketing. This procedure is known as "pumping the core."

Only water fit to drink is suitable for ice making. If a private water supply is used it must meet the standards required of municipal supplies. Frequently hard waters are softened and in some instances the supply is

passed through activated carbon filters to remove taste. Filtration through paper discs or sand filters is not necessary when the water is obtained from a modern water purification plant since the rust and other granular material dislodged from pipe lines will be entrapped in the core and removed when pumped.

The frames in which the cans of ice are supported during the freezing operation are frequently covered with heavy wooden panels. These panels provide a convenient place for workmen to walk and from which to work while placing or removing the cans or pumping the cores. The opportunity for contaminating material from the shoes of employees to fall into the cans is obvious.

Ice storage warehouses are usually kept clean but cake ice is handled crudely. Since the ice and surrounding areas are too cold for bacteria to propogate it is unusual to find coliform organisms when ice is tested. However, much could be done to improve the sanitation of loading platforms, delivery equipment, wagon grinders and consumer receptacles. Oregon has recently enacted a law regulating the manufacture and handling of ice.[17] It covers pertinent sanitary features and will be administered by the State Board of Health through a permit system. This is the first instance of the control of this industry by specific law.

## RESTAURANT CONTROL

Both the public and the restaurant business are benefited by health department supervision, since, basically, education in sanitation is a major factor of that supervision. Sanitary standards for restaurant operation are determined by state law or local ordinance. Most states have adequate laws controlling eating place sanitation as do many cities and towns. The laws are based upon a grading system or enforced by revocation of a permit. A recommended code has been formulated by the United States Public Health Service as a guide to standardize the basic sanitary concepts that should be included in local laws.[20]

### Personnel

Restaurant sanitation rests directly upon every individual working in the establishment. In-service training in the proper methods for handling foods, glassware and dishes, together with emphasis upon the necessity for good personal hygiene and neat appearance are of paramount importance.

The system of relying upon a routine medical examination given by private physicians to restaurant employees and issuance of food handlers cards does *not* assure freedom from infectious disease. These examinations are rarely sufficiently comprehensive to detect a typhoid carrier and frequently fail to restrict respiratory disease patients. The cost of these

examinations is not commensurate with the public health benefits obtained.[4, 9, 10] This is demonstrated in the recent policy established by the Illinois Department of Public Health in which routine physical examinations have been supplanted by an educational program.[16] The day to day health of employees is the most important consideration in protecting the public. Exclusion of sick persons or persons suffering from infected wounds from all food handling operations is the best control method.

An initial medical examination upon employment is advantageous since it necessarily includes a morbidity history of the patient. When the examination discloses a history of typhoid fever, diphtheria, acute tuberculosis, or any other illness indicating infections transmissible through food or drink, freedom from pathogenic infections should be confirmed by laboratory tests before the person is employed. Persons with a discharging infected wound or lesion should not be permitted to handle food, utensils, or equipment. Infections from these sources often are the cause of the staphyloccus type of food poisoning. Only as management and employees realize the importance of not working as a food handler when ill, can the incidence of these infections be eliminated.

Education of food handlers is the best means of obtaining sanitary restaurants. Health officials recognize this fact and have established training courses for food handlers in their communities. These courses cover personal hygiene, food handling, utensil and dishwashing, and insect and rodent control. They vary from a single session of 2 hours to systematic programs covering 10 or more hours with classes meeting twice weekly. This course should be compulsory for restaurant management and supervisory staff and may also be required for other employees. Some cities require completion of a prescribed food handler training course as a requisite for a food handler's certificate or permit.[11]

## Food Handling

Refrigeration of perishable foods below 40° F. is of vital importance in restaurant sanitation. Refrigerator interiors must be kept scrupulously clean and free from odors. Food must be stored in them in such a manner as to permit the free circulation of air through all parts of the storage space. Fresh meat should be suspended from hooks so that air can circulate around each piece. Salads and other foods of this type should not be used after overnight storage. If the volume of business is large a refrigerator should be provided for frequent opening and a storage box for less frequent use. Temperature control is best maintained by automatic regulation. A thermometer should be kept in each refrigerator so that the actual temperature can be determined.

Prepared foods such as salads, hash, or left-overs should be placed in

shallow pans preferably not over 3 inches deep and the food mass held to 3 inches in thickness. When large deep quantities of food are placed in refrigerators, an extended time interval may elapse before the entire food mass is chilled sufficiently to inhibit bacterial growth, particularly in the center portions. Shallower masses of food permit quicker cooling of the entire quantity, preventing hazards of staphyloccus or salmonella poisoning.

Acid drinks should not be stored in containers plated with cadmium since the acid may dissolve sufficient cadmium to give rise to chemical

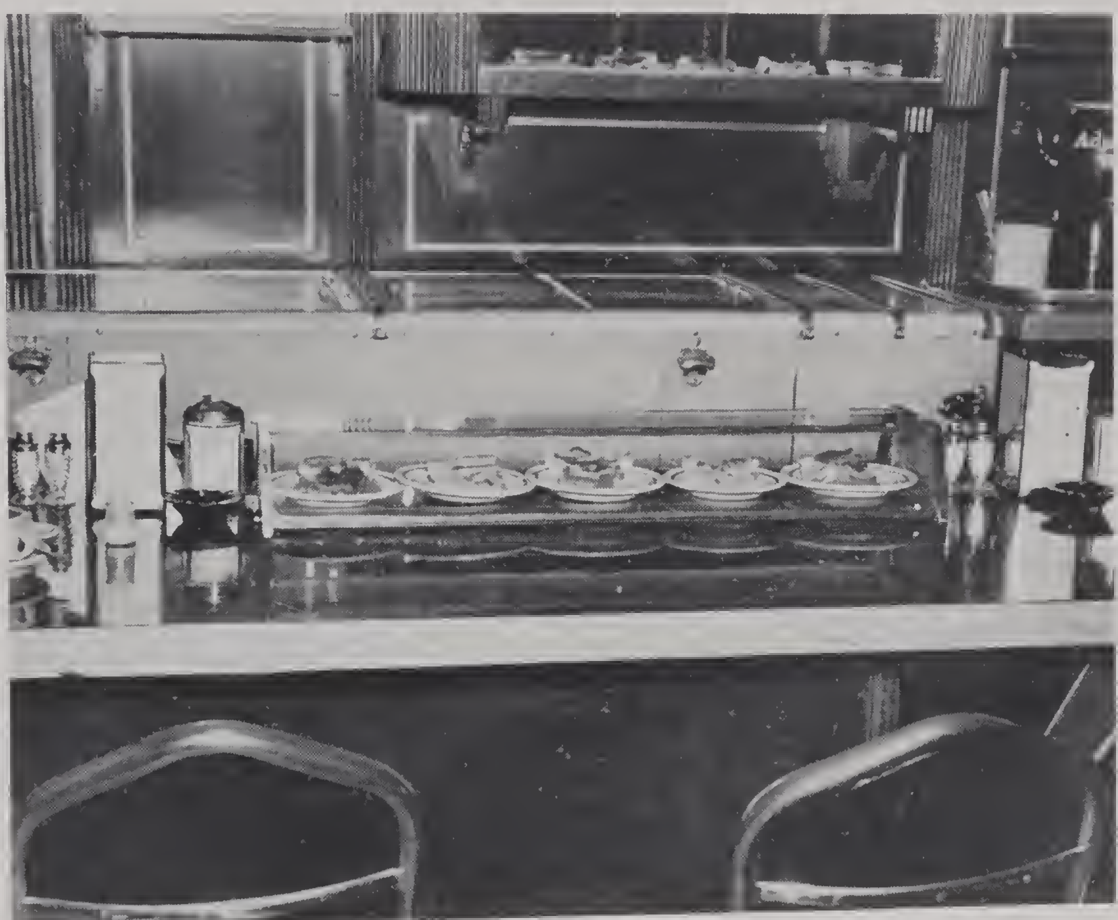

FIG. 12. Protected food display. (Courtesy, Texas Department of Health.)

poisoning to persons drinking the liquids. Cooking acid foods in galvanized iron kettles has similarly given rise to zinc poisoning.[6] Preferably, bottled drinks should not be stored in a water bath. If they are, the water should not rise higher than 2 inches below the top of the bottles.

Salads and other foods must not be mixed with the hands: a large spoon or wooden paddle should be employed. Vegetables eaten raw must be thoroughly scrubbed with clear water before use. Particular care should be exercised in preparing such foods as lettuce, celery, and watercress. Clean dry food storage rooms with containers arranged in an orderly fashion denotes a well operated establishment. Broken cartons should be discarded and the food reclaimed.

Steam tables and similar devices are used to keep food hot between preparation and serving. Unless the tables are kept clean and at a sufficiently hot temperature dangerous deterioration and contamination of the food may result. Steam tables should be drained and cleaned completely at least once each day. The temperature of foods kept in the steam tables should not be permitted to drop below 150° F., since bacterial growth and multiplication can proceed at lower temperatures. Some foods may lose in attractiveness if maintained at this temperature for an extended period of time. These should be prepared in small batches so that prolonged holding can be eliminated.

## Milk Supply

Pasteurized milk purchased from a responsible approved dealer is the best assurance of a safe supply. Customers should be served directly from the original container and the cap or seal should be removed at the time of serving. Dispensers may be permitted when the holder and pump can be easily and completely dissembled and when they are cleaned and disinfected daily. Disinfection may be accomplished by sufficiently hot water or by the use of a bactericidal solution.

## Water Supply

Hot and cold water under pressure is a necessity in a restaurant. The supply must meet drinking water standards and be adequate for all purposes.

The water supply of a restaurant is particularly important in the protection of public health. Where available, water should be obtained from an approved municipal supply. When this is not possible the private supply should be inspected carefully and tested bacteriologically, before use of the water is permitted. Only under unusual conditions should the transportation of water in cans or jugs, be allowed. If a separate supply of water from an unapproved source is used for sanitary and other purposes, such as flushing of toilets, air conditioning systems and watering of lawns, an entirely separate piping system should be used. Each water system should be painted a distinctive color and any outlets on the unapproved system should be clearly labelled to indicate its non-potable nature. No outlets on the non-potable system should be permitted in kitchens, dining rooms or any other room where food is prepared or served.

## Building

An attractive dining room or service counter encourages business. The walls should be painted a light color and kept clean. Daily cleaning of the floor is a necessity. Kitchen walls and floors should be impervious and

kept clean. Floor drains are practical, permitting daily scrubbing and flushing, and cove bases facilitate cleaning operations. All exterior windows and doors must be screened during insect seasons. Doors should open outward and be self closing. To prevent odors from penetrating the building, adequate natural or forced ventilation is necessary.

### *Dining Room*

Food displays in many instances fail to protect their contents from undue handling, flies, and droplets discharged by customers' coughing or sneezing. A properly constructed display counter is a valuable asset as well as a sanitary safeguard. Tables and counters should be as nearly impervious as practical. A well lacquered and waxed counter or wooden table top is as sanitary as a plastic one, provided cracks are not allowed to develop. Table cloths, when used, should be fresh for each patron. A soiled cloth is an affront to careful people and a detriment to business.

Broken or cracked table tops with open seams are undesirable since microscopic food films remain in them and attract insects and permit bacterial growth with resultant objectionable odors. Cracked china or glasses are difficult to sanitize so that they should be discarded. Clean dishes, silverware, and utensils must be stored above the floor in a dry place and in such a manner that they will not readily be handled or touched by surfaces that come in contact with food. They should be protected from dust. Silver should be stored with the handles in one direction, pointing toward the employee, so that removal for use will not cause fingers to come in contact with the bowls of spoons, blades of knives, or tines of forks.

### *Kitchen*

Fixed kitchen equipment should be located away from walls to prevent rodent harborage, dust collection, and to facilitate cleaning behind it. All stands, tables, and other equipment on legs should be far enough above the floor to permit cleaning and servicing but in no case should a distance less than 6 inches be permitted between the floor and the bottom shelf or panel.[10] Food preparation work tables should be of impervious material and when wood is used it should remain unpainted and be scrubbed daily. Utensils must be kept clean and bright and when not in use stored protected from dust and dirt.

Fixed equipment such as ranges, deep fat fryers, slicers, mixers, etc., must be cleaned daily. Inspections frequently disclose that this equipment is dirty due to neglect. This is particularly true for the canopy over the range. Grease collects under it, absorbs dust, and produces a layer of slime; particles from this layer frequently fall into food which is in preparation on the range.

Meat grinders, can openers, and knives must be kept clean and free from contamination. Utensils should be arranged in an orderly fashion on working shelves.

## Dishwashing

Prior to washing, dishes and utensils are scraped, usually by hand, and the refuse passed through a scraping block of neoprene or other non-grease soluble material into the garbage cans. The scraping table must be impervious, water tight and fitted with a hose spray for cleaning. Pre-washing

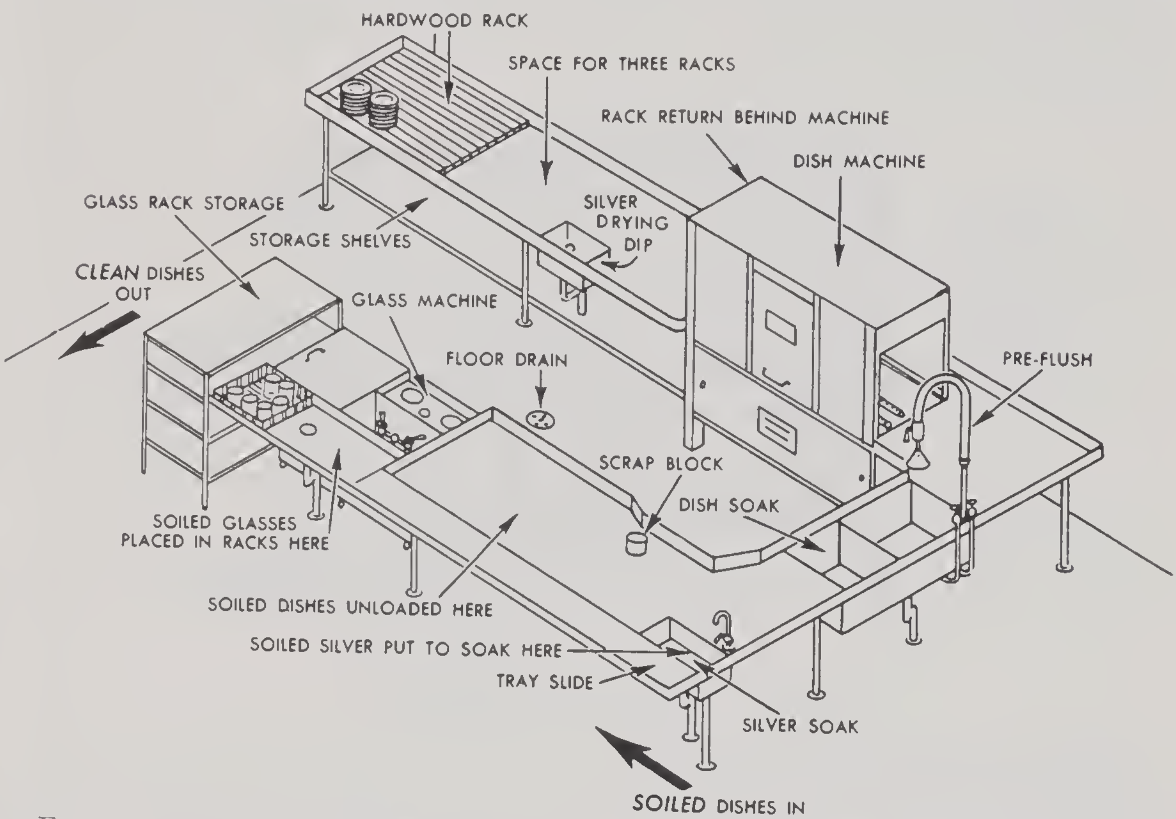


FIG. 13. Restaurant dish washing procedure. (Courtesy, Modern Sanitation and Economics Laboratory, Inc.)

machines using a hot water spray and retaining the garbage on specially designed racks are practical.

Dishes, glasses, tableware, and utensils will be satisfactorily cleaned by mechanical washers the simplest of which is a single tank, door type, dishwashing machine using a detergent applied through an automatic dispenser and having a minimum washing period of not less than 40 seconds with the wash water temperature held between 140° F. and 160° F. followed by a clear water rinse of 10 seconds duration at a temperature not less than 180° F. and with a flow of not less than 9 gallons per minute at 15 pounds per square inch pressure.[18] An adequate hot water supply has been estimated on the basis of 1.8 gallons per person per meal.[13] The problem is a complicated one, varying with the type of dishwashing

machine used, the number of dishes used per meal, and other factors. The criteria of satisfactory operation of other types of machine dishwashers vary somewhat from those described here.

Silverware and glasses must be washed separately from other dishes. All dishes and utensils should be stacked in the wash racks without crowding and in a manner that will permit the wash and rinse water to reach all surfaces of each article.

Maintenance of efficient mechanical washing requires frequent cleaning of the spray jets, detergent dispenser, and periodic removal of deposited scale from the side walls of the washer, pipes, etc., together with care and adjustment of the pumps.[3]

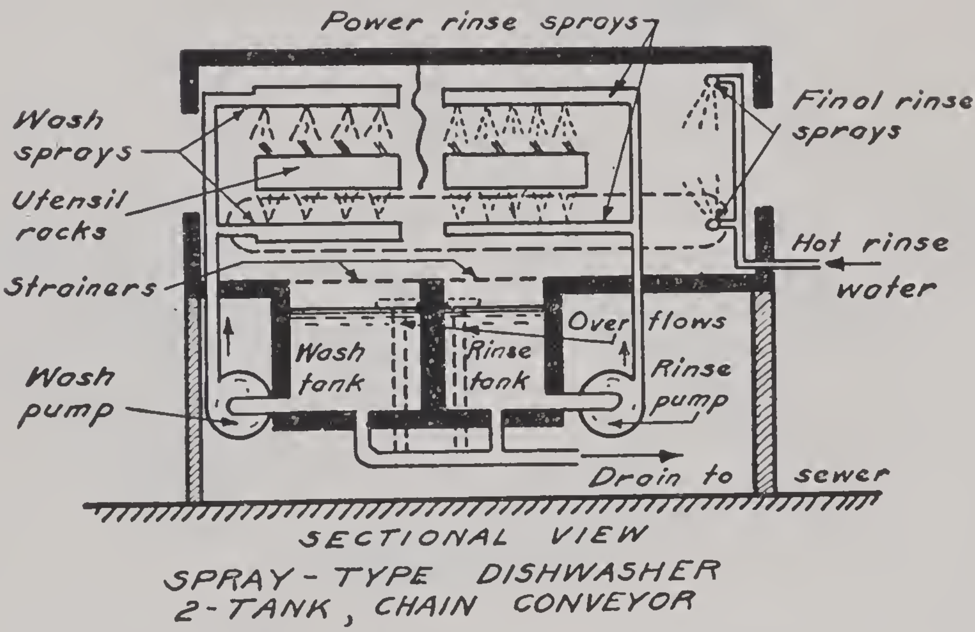


FIG. 14. Outline of a two compartment mechanical dish washer. (Courtesy, United States Public Health Service.)

When hand washed, dishes or utensils are washed in hot water at about 120° F. containing sufficient detergent to remove grease and solids, until clean to sight and touch, rinsed in hot, clear water at 140° F. and finally immersed in hot water for 30 seconds at 180° F. This procedure calls for a 3 compartment sink or separate receptacles. Immersion in hot water at 180° F. may only be accomplished by the use of trays or wire baskets since these temperatures will scald hands. The detergent water should be changed whenever the dishes are not being washed clean and the rinse water renewed whenever it becomes turbid. The pouring of scalding water over washed dishes or utensils is not a satisfactory bactericidal procedure.

Dishes and utensils may be bactericidally treated after washing and rinsing by immersing for not less than 1 minute in a warm chlorine solution having a concentration above 50 ppm. available chlorine, and then allowed to dry. Glasses may again be rinsed in hot water and allowed to drain and

dry. This operation also requires a 3 compartment sink and if additional rinsing is given from the discharge of a tap, care must be exercised to direct the flow of water into the compartment used initially for that purpose.

Immersion in warm solutions of quaternary ammonium compounds may be substituted for chlorine treatment when concentrations are adjusted "to the specific conditions of use", such as water hardness, lack of bactericidal uniformity, etc.[14] Boiling in water for 1 minute is an alternative method.

Use of chlorine solutions will turn silver and alloys black so that disinfection should be accomplished with quarternary ammonium compounds or by boiling in water for 30 seconds.

Dishes and utensils should be air dried. However, if drying cloths are used they must be clean and used for no other purposes.

Adequate hot water is a necessity. Booster heaters to maintain the temperature at 180° F. should be installed in the water line leading to the rinse section of the dishwasher. It is questionable whether burners placed under the compartment sink will maintain temperatures required for sanitizing. Water temperatures in the dishwasher or compartment sink must be checked by thermometers. Washing machines should have thermometers built in them.

The efficiency of dishwashing methods is usually determined by the "swab test." The average plate count per utensil, when not less than 4 similar utensils have been subjected to the test, should not exceed 100 colonies.[15]

## Waste Disposal

Garbage should be kept in tight metal containers. The cans should be tightly covered and cleaned daily. The rack or area upon which the cans are stored should be of an impervious material and be kept clean and periodically sprayed with DDT. Many restaurants now use refrigerated rooms for storage of garbage. Proper garbage disposal has its importance in rodent and insect control and in esthetics.

Overhead sewer lines should not pass through food preparation rooms, kitchens, dining rooms, or storage rooms. Sewer lines may develop leaks and the leakage may drop on food or utensils if they are stored directly under these lines. Direct cross connections from sewer lines or unapproved water supplies to an approved water supply should not be permitted. Privies or septic tanks with tile fields that meet state health department requirements are satisfactory sewage installations in rural localities. Good maintenance of all disposal facilities is necessary to minimize the possibility of spreading pathogenic organisms by flies or other insects.

Hand washing facilities for all restaurant personnel must be adequate

in number and convenient in location. Special attention should be given to these criteria in those establishments served by privies.

### Insect and Rodent Control

An insect and rodent control program using DDT or other insecticides, and red squill, trapping or, in extreme instances, Antu as rodenticides is the only satisfactory method to eliminate these pests. Employment of a reliable commercial exterminator, who is a trained entomologist, to give periodic service in all phases of this control, is usually the most economical procedure.

Screening of the building is an important measure in fly control. Clean walls and elimination of cracks will do much to reduce roach populations, and proper building construction will keep out rodents. Details of these procedures are found on page 390. Cats, dogs, and other animal pets must not be kept in restaurants. It is difficult to control the hygienic habits of humans; pets cannot be held responsible for public health concepts.

### Toilets

There is no public health reason why restaurants should be required to have *public* toilets. However, the convenience of the patrons will probably necessitate the provision of these facilities. Some local ordinances require that toilets be provided. The important consideration is that where they are available, they be kept clean to prevent unpleasant odors. Impervious or well painted floors and walls make the cleaning task much easier. All toilet rooms should have a direct connection to the outside for ventilation.

Adequate toilet and lavatory facilities must be provided for the restaurant staff. As with any facilities provided for the public, these should be kept clean and attractive. Soap or some other detergent should be provided as well as single-service towels. Prominent signs should remind employees to wash their hands thoroughly after using toilets. No one should be permitted to work after using the toilet without washing his hands. This rule should be rigidly enforced even though it may mean discharging violators.

Toilet rooms should not open directly into food preparation or storage rooms. In large establishments, hand washing facilities should be provided convenient to work areas, in all cases at least on the same floors where food preparation or serving work is done. Separate toilet rooms should be provided for each sex. Toilet room doors must be self-closing and windows be screened. Toilet and lavatory facilities separate from those provided for the public are preferable.

Dressing rooms or adequate lockers should be provided for employees. Soiled coats, aprons and other linens should be kept in containers until laundered.

## Restaurant Inspection

An inspection chart is shown in Figure 15 covering all phases of restaurant operation. It should be remembered that conditions reported reflect

FEDERAL SECURITY AGENCY
PUBLIC HEALTH SERVICE
(July 1941)

*Sources*

Milk ..............................
Cream ..............................
Ice cream ..............................
Shellfish ..............................

**Inspection Form for Eating and Drinking Establishments**

.............................................................................
(City, county, or district)

Type ..............................
No. served daily ..............
Any kitchen maintained elsewhere? ..................

NAME ........................................................................ ADDRESS ........................................................................

SIR: An inspection of your premises has this day been made, and you are notified of the defects marked below with a cross (x). Violation of the same item on two successive inspections requires immediate degrading or suspension of permit. All menu cards or boards shall display grade ________ notice.

Item No.*

(1) Floors.—Easily cleanable construction, smooth, good repair ( ), clean ( ).............. (B )

(2) Walls and ceilings.—All: clean, good repair ( ); kitchen: light color ( ), walls smooth, washable to level of splash ( ), no splash or spray above surfacing ( )... (B )

(3) Doors and windows.—Outer openings with effective screens and outward-opening, self-closing doors, or fly-repellent fans, or flies absent .............................................. (C )

(4) Lighting.—Natural or artificial light equivalent to 10 foot-candles 30 inches above floor, except in dining room.......................... (B )

(5) Ventilation.—All rooms (except cold storage) reasonably free of odors and condensation ... (B )

(6) Toilet facilities.—Comply with plumbing code ( ), adequate, conveniently located for employees ( ), good repair, clean, no flies ( ), well lighted, outside ventilation ( ), in new establishments, no direct opening ( ), self-closing doors ( ), washing sign for employees ( ), privies, if used, comply State standards ( )........................................ (C )

(7) Water supply.—Easily accessible, adequate ( ), safe, complies State standards ( ) ................................................ (C )

(8) Lavatory facilities. — Adequate, convenient ( ), warm water ( ), soap ( ), approved sanitary towels ( ), hands washed after toilet ( )........................ (C )

(9) Construction of utensils and equipment.—Easily cleanable construction, no corrosion ( ), good repair, no open seams, no chipped or cracked dishes ( ).............. (C )

(10a) Cleaning of equipment and utensils.—Clean cases, counters, shelves, tables, meat blocks, refrigerators, stoves, hoods ( ), clean cloths used by employees ( ), single-service cups, plates, straws, caps used only once ( ); eating and drinking utensils thoroughly cleaned after each use ( ), other utensils each day ( ).............. (C )

(10b) Bactericidal treatment of eating and cooking utensils.—Approved bactericidal treatment after cleaning: immersed 2 minutes in 170° F. water, or one-half minute in boiling water, or 2 minutes in approved chlorine rinse; or kept in steam cabinet 15 minutes at 170° F. or 5 minutes at 200° F.; or in hot air cabinet 20 minutes at 180° F. ( ); cabinets have thermometer in coldest zone ( ); large utensils adequately treated with live steam, boiling water, or chlorine spray or swab ( ); washing machines produce utensils within bacterial standard ( ); drying cloths, if used, kept clean and used for no other purpose ( )...................... (C )

(11) Storage and handling of utensils.—Stored above floor in clean place protected from flies, splash, dust, etc., inverted or covered when practicable ( ), no handling of contact surfaces ( ), single-service cups, straws, etc., purchased in sanitary cartons, kept in clean dry place, and properly handled ( ), dispensing spoons, dippers kept in hot or running water ( )........... (C )

(12) Disposal of wastes.—Liquid wastes into public sewer or as approved by State ( ), no connection or back-siphonage into water supply ( ); garbage stored in tight, nonabsorbent, washable receptacles, covered pending removal ( ), removed frequently and receptacles washed to prevent nuisance ( )................................................ (C )

(13) Refrigeration.—Readily perishable foods (including cream-filled pastry) stored at 50° F. or less ( ), ice stored and handled in approved manner ( ), drip enters open trapped drain or pan ( ) .................. (C )

(14) Wholesomeness of food and drink.—Wholesome, no spoilage ( ); milk, fluid milk products, frozen desserts from approved sources ( ), milk, etc., served in original bottles or from approved bulk dispenser ( ), shellfish from approved sources ( ) ................................................ (C )

(15) Storage and display of food and drink.—No contamination by overhead leakage, submerging, or unnecessary handling ( ), not on floors subject to flooding from sewage backflow ( ), no animals, fowls, rodents, roaches, etc. ( ), flies under control ( ), no open displays ( ), floor cleaning only after closing or between meals, by dustless methods ( )................... (C )

(16) Cleanliness of employees.—Clean outer garments used for no other purpose ( ), hands clean ( )................................ (C )

(17) Miscellaneous.—Premises kept neat and clean ( ); no operations in living or sleeping rooms ( ), clean, adequate lockers for employees' clothing ( ), soiled linens, coats, aprons kept in containers ( )..... (B )

REMARKS: ........................................................................................................................

Date ..............................

........................................
*Inspector.*

* The item numbers correspond to those for grade A in 1940 U. S. Public Health Service Restaurant Ordinance. For "itinerant restaurant" requirements see Code.

FIG. 15. Inspection form for restaurants. (Courtesy, United States Public Health Service.)

the situation at the time of the inspection. Circumstances may be better or worse within a short time after the survey, depending upon the training of the personnel. Odors disclose many unsatisfactory conditions.

Any inspector will do well to remember that restaurant employees are human and are likely to shirk the more onerous tasks or slight conditions that are less obvious. In any event, a cooperative and helpful attitude on the part of the inspector will bring best results.

## CARNIVALS, CHURCH FAIRS AND SUPPERS

Preparation of food for church suppers and similar functions has caused many outbreaks of food poisoning. Salads have been the principal offenders, due primarily to the fact that they may have been prepared many hours prior to consumption and improperly refrigerated. In most instances multi-service dishes and tableware are hand washed under the necessity of quick replacement and are not properly sterilized by immersion in 180° F. or in a germicide solution. Single service utensils are particularly suitable for this type of operation. The safeguards and procedures discussed for restaurant sanitation apply and should be strictly enforced. The fact that the handling of food is a temporary activity does not alter the necessity for good sanitary practice.

Sanitary control is a problem for the health officer. It obviously is a matter of good educational programs which may be furthered through enlisting the aid of clergymen, ladies aid societies, and similar organizations to introduce proper food handling procedures.

## LUNCH AND SODA COUNTERS

Soda fountains and luncheonette sanitation is similar to restaurant sanitation. All phases concerning food protection, preparation and storage, dishwashing, food handlers and food displays apply.

Single service cups, plates, aprons and paper napkins, stored in closed receptacles prior to use, should be used at the soda fountain unless adequate dishwashing facilities are available. Ice cream cabinets, ice storage compartment, syrup dispensers, wooden sandwich boards and mixers must be kept scrupulously clean. Spoons and dippers used to serve ice cream must be kept in running water.

Toilet and lavatory facilities frequently are inadequate in luncheonettes and soda fountains. Likewise garbage storage and disposal is likely to be unsatisfactory. There is no reason why all of these facilities should not be as satisfactory as in restaurants.

## STORES AND MARKETS

Retail food stores should be kept clean and present a good appearance. All factors governing food storage, refrigerator sanitation and personnel

habits stated for restaurant operation apply. Slicers, grinders, knives, saws, butcher blocks, and other meat cutting equipment must be cleaned daily and kept free from rust. Unwrapped, pre-cooked foods and meats should be kept in protected display cases. Good sanitation habits attract customers to the large food market or small corner store.

Fig. 16. A modern food market. (Courtesy, Modern Sanitation and Los Angeles Health Department.)

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## Chapter V

# MILK AND MILK PRODUCTS

Milk and its products are of primary importance to public health. On the positive side, there is the food value of milk, which has been described as the most nearly perfect food available. Phosphorus, iron, proteins, fats, and vitamins A and G are the more important food components. Vitamins B, C, and D are also present.

## DISEASE TRANSMISSION

Unfortunately just as milk is a food for man it is also a good food for micro-organisms. Many of the pathogenic bacteria, when introduced by an infected cow or by human contamination, grow luxuriantly in milk at suitable temperatures. The first milk-borne epidemic of which there is any record occurred in Penrith, England, and was noted by M. W. Taylor[16] in 1857. Since then many outbreaks and cases of communicable disease have been traced to milk and its products. The advent of modern hygienic control of milk production has not eliminated the possibility of milk-borne disease. Between the years 1938 and 1948, as reported by state and municipal health departments, milk and its products were found responsible for 376 outbreaks, representing 15,924 cases of illness, and 103 deaths in the United States.[24]

Diseases of importance to man that have their origin in the cow or goat include tuberculosis, undulant fever (brucellosis), and, of recent determination, Q fever.[4] There are indications some of the salmonella organisms, in addition to typhoid and paratyphoid, may be transmitted to milk by infected cows. Diseases transmitted through milk contaminated in production, or through handling include diphtheria, scarlet fever, septic sore throat, and the dysenteries of the food infection type.

## OFFICIAL REGULATIONS

It is not surprising that the control of milk production and its sale has been accepted as a necessary function of government. On the one hand there is the encouragement of the use of milk as a food because of its unique value. The economic investment in and income from the industry is likewise of great importance. Contrasted with these interests is the prevention of disease that may be transmitted by infected milk and its products. Prevention of disease is a fundamental responsibility of health departments. Protection of the economic life of the dairy farmer is a similar function of the department of agriculture.

Milk regulations originate with state agencies. Both the state health department and the state agriculture department are involved in this control. Generally, sanitary requirements are a function of the health department, although in a few states the department of agriculture not only has control of economic factors of the dairy industry but also of certain health aspects. In some states, separate milk control boards have these responsibilities. The first milk control law was passed in Massachusetts in 1856.[16]

In most states the local health department, municipal, county, or district is the agency ultimately responsible for the control of milk production and sale. State regulations may exist but the local health department

TABLE 2

*Number of Milk-Borne Epidemics in the United States (1923–1948, inclusive)*

| | Outbreaks | Cases | Deaths |
|---|---|---|---|
| All diseases | 1,013 | 41,838 | 813 |
| Diphtheria | 18 | 324 | 13 |
| Dysentery | 23 | 1,554 | 21 |
| Gastro-enteritis (including food infections and food poisoning) | 234 | 10,988 | 20 |
| Paratyphoid fever | 28 | 1,091 | 22 |
| Scarlet fever and septic sore throat | 203 | 19,257 | 182 |
| Typhoid fever | 445 | 7,524 | 548 |
| Undulant fever | 41 | 347 | 3 |
| Miscellaneous | 21 | 753 | 4 |

United States Public Health Service—"Summary of Disease Outbreaks from Water, Milk and Milk Products", Div. Sanitation, Mar. 1950.

adopts its own ordinances, which must be at least as stringent as those set by the state. These ordinances regulate chemical and bacterial standards, methods of production and sale, and licensing. New York City adopted definite bacterial standards in 1901, and Chicago became the first city to require pasteurization, excluding certified milk, in 1908.[16]

Since the source of milk is not always in the state in which the milk is consumed, state and municipal laws frequently conflict. This confusion has created a problem, handicapping farmers who produce milk that enters more than one regulatory jurisdiction, and resulting in uncertainty about sanitary milk production. The United States Public Health Service was called upon for help in establishing rules and regulations that could be accepted by all regulatory agencies in order to give uniformity in the hygienic control of milk production.[22, 26] A "standard" milk ordinance and code was initially published in 1924, and has been frequently revised.[23]

Although this ordinance and code has no legal standing *per se* it has been adopted by many communities. It has helped markedly in reducing the confusion in administration that existed prior to 1924.

## DEFINITIONS

The following definitions taken from the Code describe some of the terms used frequently. Additional terms will be used in subsequent parts of the chapter and described at that time.

**Milk.** "The lacteal secretion, practically free from colostrum, obtained by the complete milking of one or more healthy cows, which contains not less than $8\frac{1}{4}$ per cent of milk solids not fat and not less than $3\frac{1}{4}$ per cent of milk fat." The same definition, with appropriate substitution of "goat", defines goat milk.

**Cream.** "A portion of milk which contains not less than 18 per cent milk fat."

**Skim milk.** "Milk from which a sufficient portion of milk fat has been removed to reduce its milk fat percentage to less than $3\frac{1}{4}$ per cent."

**Homogenized milk.** "Milk which has been treated in such manner as to insure break-up of the fat globules to such an extent that after 48 hours quiescent storage no visible cream separation occurs on the milk and the fat percentage of the top 100 ml. of milk in a quart bottle, or of proportionate volumes in containers of other sizes, does not differ by more than 10 per cent of itself from the fat percentage of the remaining milk as determined after thorough mixing."

**Pasteurization** "The process of heating every particle of milk or milk products to at least 143° F., and holding continuously at such temperature for at least 30 minutes, or to at least 161° F., and holding at such temperature continuously for at least 15 seconds, in approved and properly operated equipment."

**Milk producer.** "Any person who owns or controls one or more cows, a part or all of the milk or milk products from which is sold or offered for sale." Producers are sometimes classified into "producer-dealers" and "plant producers". The former term refers to those producers who retail all or part of the milk produced; the latter refers to those who sell all of the milk produced to a milk plant.

**Milk distributor.** "Any person who offers for sale or sells to another any milk or milk products for human consumption as such."

**Dairy or dairy farm.** "Any place or premises where one or more cows are kept, a part or all of the milk or milk products from which is sold or offered for sale."

**Milk plant.** "Any place or premises or establishment where milk or milk products are collected, handled, processed, stored, bottled, pas-

teurized, or prepared for distribution, except an establishment where milk or milk products are sold at retail only."

### Average Bacterial, Direct Microscopic, and Coliform Count

The logarithmic average of the bacterial plate counts and direct microscopic counts, of the last four samples of milk taken are used since experience has shown that the use of arithmetic averages may work an unwarranted hardship on the producer. This can be understood if four samples are considered, one of which has a count of 1,000,000 (possibly because of poor refrigeration) and the other three, 20,000 each. The arithmetic average is 265,000 whereas the logarithmic average is 53,180. The latter count is accepted as a fairer one.

### Methylene Blue or Resazurin Reduction Time

A standard laboratory test used to determine the length of time required for a sample of milk to decolor the dye, methylene blue or resazurin, added to the milk. This time varies with the bacterial quality of the milk: the better the quality, the longer the reduction time. Since the resazurin test is shorter than the methylene blue test, it is gaining in popularity.

The test is applied to raw milk. The results give only an approximation of the number of bacteria present. A good milk will have a resazurin time of 4 hours.

### Grades of Milk

From a theoretical viewpoint there seems to be no reason why milk should have more than one grade—a safe grade. However, a compromise between perfection and practicality is often necessary even in public health practices. Milk ordinances frequently recognize different grades, both in pasteurized and raw products. The less rigid grade usually sells for a cent or two less a quart; practical considerations are allowed in this way to affect theoretical ones. The producer is considered also since the price paid is dependent on the grade of milk. Were there only one grade, the best, many farmers would be unable to sell their product. This could result in a severe hardship to the consumer in those areas where the dairy industry has not developed the highest standards. Fortunately, pasteurization will render any reasonably good raw milk safe. (The public health goal is a clean good raw milk made safe by pasteurization.) Many cities permit only one grade of milk as far as hygienic grades are concerned. Grades based upon butterfat content or production by a specific breed of cattle, e.g. Guernsey, Jersey, etc. may be permitted.

The Code recognizes grades based on sanitary criteria. Dairy farm

facilities and production methods enter into the classification. So do laboratory findings, as shown by the following:

*Laboratory Examination Criteria of Grades of Milk*

| | Sold as Raw Milk | Sold as Pasteurized Milk: Raw Milk | Sold as Pasteurized Milk: Pasteurized milk |
|---|---|---|---|
| *Grade A.* | | | |
| Bacterial plate count, not more than.... | 50,000 per ml. | 200,000 per ml. | 30,000 per ml, |
| Methylene blue reduction time, not less than......... | 7 hours | $5\frac{1}{2}$ hours | |
| Coliform count, not greater than...... | | | 10 per ml. |
| *Grade B.* | | | |
| Bacterial plate count, not more than.... | 200,000 per ml. | 1,000,000 per ml. | 50,000 per ml. |
| Methylene blue reduction time, not less than......... | $5\frac{1}{2}$ hours | $3\frac{1}{4}$ hours | |

Certified milk is the milk produced in accordance with the requirements of the American Association of Medical Milk Commissions. Many municipalities require the pasteurization of this grade as well as all other milk. The premium price charged for certified milk plus the high quality of the general milk supply has reduced the sale of this premium milk in many areas.

A grade of "C" is also covered in the "standard" ordinance. Where recognized, this grade is usually accepted only for processing or manufacturing purposes.

## Bacterial Counts

Bacterial counts are based either upon agar plate counts or direct smear counts. Plate counts have the advantage of measuring only viable organisms or clumps of organisms which grow between 32° C.–37° C. in the sample, and of being particularly applicable to samples with low counts. They are time-consuming, require a greater quantity of material and equipment than does the direct count technique, and types of organisms cannot be identified readily.

Direct counts made from stained smears have the advantage of speed, a minimum of necessary materials and equipment, and the ability to identify types of organisms. The latter characteristic is important in identifying causes or sources of bacterial content. Direct counts have the disadvantage of requiring continued and careful search for bacteria in samples

with low counts: variation in the retention of stains in the cells; and small samples upon which the count is based.

Coliform density is coming into greater acceptance as a measurement of milk quality than was the case 10 years ago. Good milk properly pasteurized and handled should be free from coliform organisms. Any of these organisms in properly pasteurized milk is now recognized as indicating post-pasteurization contamination.

### Phosphatase Test

This colorimetric test determines the completeness of pasteurization. The enzyme phosphatase is present in all raw milk. It will liberate phenol from phosphoric phenyl esters. Heating inactivates the phosphatase and so a measurement of the degree of inactivation of the phosphatase reveals the efficiency of pasteurization. All the phosphatase is not inactivated with heat treatment of 143° F. for 30 minutes or 161° F. for 15 seconds. The amount of phosphatase remaining under these conditions amounts to 1 unit, the maximum allowable for properly pasteurized milk.[18]

This test is unusually versatile in that it will detect under-pasteurization due to too low a temperature or too short a heating period. It will also detect the addition of raw milk to properly pasteurized milk, or milk that may enter the pasteurized product through leaky or incompletely closed valves. Detection can be made of faulty points in the pasteurization process if samples of the processed milk are taken from several points in the distribution system. See page 90.

### Sediment Test

This test determines the amount of undissolved visible dirt in milk. It is performed by forcing a fixed quantity of milk through specially prepared filter pads. The results give a crude measure of the care with which the milk has been handled on the diary farm.

## MILK PRODUCTION

Success in the sanitary control of a milk supply is invariably associated with a good spirit of cooperation between producers and the health department. In no other phase of health department activity is education a more potent tool. To be sure, an adequate code must be available for use when necessary. The producer, though, must be convinced of his moral obligation to produce a safe product and shown that his own economic welfare is associated closely with a good product. This can be done and is done. Many large commercial producers now conduct their own educational programs among the diary farmers from whom milk is purchased.

## The Dairy Farm

Pasteurization will render a reasonably good milk safe. However, the goal of public health supervision of milk supplies is to assure a good raw milk supply, with pasteurization as a safety factor. A good raw milk means healthy cows, clean premises, good methods and equipment, and healthy personnel to handle the milk. The health department program should consider all of these factors.

**Healthy Animals.** Healthy cows and goats can be obtained only through a good veterinary program. Chronic illnesses such as tuberculosis and undulant fever can be detected by simple tests performed by trained veterinarians. Many states with the cooperation of the Federal Bureau of Animal Industry offer testing services and indemnification to the farmer to cover part of the loss incurred when infected animals are found and removed from the milking herd. Accredited areas have been established, indicating an incidence for each disease less than a certain minimum basis.

Human streptococcic infection may be transmitted to cows by the milkers. These infections usually follow an infection of one or more teats of the cow with mastitis. *Streptococcus agalactiae*, non-pathogenic to man, is the principal agent causing mastitis. This non-pathogenic infection apparently pre-disposes the udder to infection by organisms which are pathogenic to man. Control of these infections is best carried on under the direction of a veterinarian. A well trained sanitarian should be able to handle most of the educational work. The dairy farmer has an economic interest in the control of mastitis infections since milk production from affected animals is seriously decreased.

Other diseases such as typhoid fever and diphtheria may be transmitted by milk contaminated directly by the diary personnel. Good personal hygiene is the method of prevention in the spread of these infections. The hazard of an unsafe water supply must also be considered in preventing the spread of typhoid or paratyphoid through milk.

**Premises.** The important features of the premises are the dairy barns, milking parlor or stable, milk house or room, dairy yard, and the water supply and sewage disposal facilities. Whatever standards are adopted should be based upon sound public health practice.

Two general types of barns are used for sheltering cows, particularly in unseasonable weather. The more common is the stall or stanchion type in which each cow is kept in a particular stall or stanchion. The second type is the pen barn in which all the animals are maintained in a single room in which they are free to move. There are advantages to each type, just as there are disadvantages. In the stanchion type the cattle can be kept cleaner and injury by other cows is prevented. In the pen type the cow

Form 8976-D
FEDERAL SECURITY AGENCY
PUBLIC HEALTH SERVICE
(Rev. May 1944)

Budget Bureau No 68-R172.
Approval expires 10-31-47.

## MILK PLANT—PRODUCER INSPECTION FORM

GALLONS SOLD DAILY TO

........................ *Plant*

Whole milk........ ........
Skim milk........ ........
Cream........ ........
TOTAL........ ........

........................ (City, county, or district) ........

NAME ........................ LOCATION ........................

SIR: An inspection of your dairy has this day been made and you are notified of the defects marked below with a cross (X). Violation of the same item on two successive inspections calls for immediate degrading.

*Item No.*[1]

### COWS

(1) *Tuberculosis and other diseases.*—Tuberculin test annually except in modified accredited counties ( ), evidence on file ( ), other tests as required ( ), no cows with extensive induration of udder ( ), no cows giving abnormal milk ( )........ ( )

### DAIRY BARN

(2) *Lighting, milking barn.*—Adequate light openings ( ), windows clean ( ), adequate artificial light for night milking ( )........ ( )

(3) *Air space and ventilation.*—Well ventilated ( ), no overcrowding ( )........ ( )

(4a) *Floor construction, milking barn.*—Floors and gutters, concrete, tight wood, or other impervious and easily cleaned material in good repair ( ), graded ( ).. ( )

(4b) *Floor cleanliness, milking barn.*—No accumulations beyond one milking ( ), no horses, pigs, fowl, calves, etc. ( )........ ( )

(5) *Walls and ceilings.*—Painted biennially or whitewashed annually or other satisfactory finish ( ), clean and in good repair ( ), ceiling tight if feedstuffs over ( ), feed-room partition dust-tight with door ( )........ ( )

(6a) *Cow yard, grading and draining.*—Graded ( ), drained ( ), no pooled wastes ( )........ ( )

(6b) *Cow yard, cleanliness.*—Clean ( ), no swine ( ).. ( )

(7) *Manure disposal.*—Stored inaccessible to cows and, during fly season: (*a*) Spread upon fields, or (*b*) piled not more than 4 days and then spread, or (*c*) stored not more than 7 days in impervious bin or curbed platform and then spread, or (*d*) stored in tight, screened, and trapped manure shed, or (*e*) fly breeding minimized by other approved methods........ ( )

### MILK HOUSE

(8a) *Floors.*—Smooth concrete or other impervious material ( ), graded to drain ( )........ ( )

(8b) *Walls and ceilings.*—Smooth dressed lumber, sheet metal, or plasterboard, well painted with washable paint; hollow tile, cement blocks, bricks, concrete, or cement plaster, surfaces and joints smooth........ ( )

(8c) *Lighting and ventilation.*—Effective window area at least 10 percent of floor area ( ), adequate artificial lighting (see Code) ( ), adequate ventilation ( ), doors and windows closed during dusty weather ( )........ ( )

(8d) *Screening.*—All openings effectively screened and doors open outward and self-closing, unless flies otherwise kept out........ ( )

(8e) *Miscellaneous requirements.*—Used for milk purposes only, except by permission ( ), milk house operations not conducted elsewhere ( ), no opening into living quarters or stable ( ), wastes properly disposed of ( ), 2-compartment stationary wash and rinse vats ( ), adequate water-heating facilities ( )........ ( )

(9) *Cleanliness and flies.*—Floors, walls, windows, shelves, tables, and equipment clean ( ), no trash or unnecessary articles ( ), all necessary fly-control methods ( )........ ( )

*Item No.*[1]

### TOILET

(10) *Toilet.*—Conveniently located ( ), constructed and operated according to Code ( ), no evidence of defecation or urination about premises ( )........ ( )

### WATER SUPPLY

(11) *Water supply.*—Easily accessible ( ), adequate ( ), no surface or cistern water unless approved ( ), safe, sanitary quality (see Code) ( )........ ( )

### UTENSILS

(12) *Construction.*—Smooth heavy-gage material ( ), corrosion-proof surface, no agateware ( ), easily cleanable shape ( ), joints soldered flush ( ), good repair ( ), no woven-wire cloth ( ), milk pails small-mouth design ( )........ ( )

(13) *Cleaning.*—Cleaned after each usage ( ), must look and feel clean ( )........ ( )

(14) *Bactericidal treatment.*—Steam cabinet 170° F. for 15 minutes or 200° F. for 5 minutes, or steam jet 1 minute, or immersed in standard chlorine or 170° F. water for 2 minutes, or flow of 170° F. water at outlet for 5 minutes or standard chlorine for 2 minutes, or hot-air cabinet 180° F. for 20 minutes ( ), cabinets have thermometer in coldest zone ( )........ ( )

(15) *Storage.*—Left in treating chamber until used or stored inverted in protected place in milk house ( ), cotton disks in original package in cabinet until used ( )........ ( )

(16) *Handling.*—After bactericidal treatment, no handling of surfaces to which milk is exposed........ ( )

### MILKING

(17) *Udders and teats.*—Clean ( ), rinsed with standard chlorine solution at time of milking ( ), abnormal milk excluded ( )........ ( )

(18) *Flanks.*—Flanks, bellies, and tails free from visible dirt at time of milking ( ), brushing completed before milking begun ( )........ ( )

(19) *Milkers' hands.*—Clean ( ), rinsed in standard chlorine solution just before milking each cow ( ), dry while milking ( ), hand-washing facilities including soap, water, and individual clean towels convenient to milking barn ( )........ ( )

(20) *Clothing.*—Clean outer garments........ ( )

(21) *Milk stools.*—Clean, not padded ( ), stored above floor ( )........ ( )

(22) *Removal of milk.*—Immediate removal to milk house or straining room ( ), no straining in barn ( ), can covered, protected from manure and splash ( )........ ( )

(23) *Cooling.*—Milk either delivered to plant, or cooled to 70° F., within 2 hours after milking completed........ ( )

### MISCELLANEOUS

(26) *Vehicles.*—Clean ( ), covered ( ), no contaminating substances transported ( ). *Premises.*—Surroundings kept neat and clean ( )........ ( )

Remarks ........................

Date ........................ ........................ *Inspector.*

[1] Item numbers correspond to item numbers for Grade A raw milk (for pasteurization) in 1939 edition (as amended Dec. 8, 1942) of United States Public Health Service Milk Ordnance and Code, to which please refer. The requirements for Grade B raw (for pasteurization) are the same except for the bacterial standard.

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.—Price 85 cents per pad of 100.

U. S. GOVERNMENT PRINTING OFFICE 16—23905-3

FIG. 17. Dairy farm inspection form. (Courtesy, United States Public Health Service.)

manure is kept covered with fresh bedding. The decomposition of the manure provides a certain amount of heat to keep the barn warm. The cows are more contented when allowed to move about and there is less

danger of self-inflicted injury. There is less udder injury among cattle kept in pen barns than in those kept in stanchions.

Either type of barn must be kept clean, well ventilated and lighted. Walls and ceilings should be whitewashed yearly or painted once every two years. Lighting both natural and artificial should be adequate to assure proper cleaning.

The floors of the stanchion type barn should be of an impervious material so that dirt will be visible and then can be kept clean easily. Concrete provides the most satisfactory material. The gutters in which the feces and urine drop should also be of impervious material. They should be graded to drain properly.[11] In new construction, 4 square feet of window space per stanchion should be installed to provide for adequate lighting and ventilation. Windows and doors should be screened. Manure should be removed at least once and preferably twice daily. In either type of barn other animals and poultry should be kept out.

A separate room should be provided for milking purposes.

## Dairy Farm Sanitation

The milking room floor must be impervious, constructed to prevent pooling of water and sloped to a drain. Manure gutters must be of concrete or other impervious material. Portions of the barn used to stable the cows, for feed storage, etc. should be separated from the milking room by dust tight partitions. If there is a floor over the milking room a tight ceiling should be provided. The milking room floor should be cleaned by scrubbing or brushing after each milking.

Fly control by the use of DDT or other suitable insecticide is essential. The walls, ceiling, screens, and other surfaces not washed daily should be treated twice during the summer to assure eradication of flies from the dairy barn. Care should be exercised to protect feed and animals from the DDT spray. Methoxychlor or lindane, in preference to DDT, is now recommended for use in dairy buildings.

The barn yard should be graded and well drained to prevent the cows from wading through mire or piles of manure when entering or leaving the barn. Care must be exercised to drain the waste from the barn and dairy so that it will not form a pool in the cow yard in which the cows may become soiled. Manure should be removed daily from the yard and the barn. It should be spread upon the fields as quickly as possible, at least every 7 days and preferably oftener. If it is necessary to place it in a compost pile it must be stored on an impervious platform, be inaccessible to the cattle, and the liquid wastes from it not permitted to drain into the cow yard. Accumulations of manure provide fly-breeding material *par excellence*. The use of insecticides such as DDT, chlorodane or lindane on

the piles and adjacent areas will decrease fly-breeding. Piles of manure lose much of their fertilizer value by the leaching action of rain.

## Milk House

A milk house or dairy is provided to enclose the milk handling operations. This may be a separate building or a room in the dairy barn. It should not open directly into the barn but must be separated from it by a screened passageway. Windows must be screened and all doors must be self closing,

Fig. 18. Properly kept barnyard, Alto Medical Center, Alto, Ga. (Courtesy, Georgia Department Public Health.)

open outward, and be screened. The room must be well lighted both by natural and artificial light, have ample ventilation and impervious floors, preferably concrete, sloping to a drain. Hot and cold water under pressure and adequate washing vats or sinks should be provided. Ample storage for utensils must be available in a protected dry place. The milk house or room should not be used for any other purpose than to handle milk and it must be kept scrupulously clean. All pets must be excluded. When kept in good repair and painted frequently walls and ceiling may be made of wood. Window space should be equal to 10 per cent of the floor area and be evenly distributed. If milk is to be sold raw, the milk handling and utensil washing portions should be separated by a solid partition; it is

important to keep flies from the milk room. Since milk absorbs odors, nothing that may give off odors, including gasoline engines, should be in the milk house.

All human excreta must be disposed of by connection to a sewer, properly constructed and operating septic tanks, or by fly-tight privies. The toilets should be located conveniently and kept clean. Wash water from the milk house must be disposed of to a sewer or through a properly constructed and operated septic tank or soakage pit.

The water supply used in all dairy operations must be bacteriologically safe and adequate to meet all the needs of milk production. Well water, if used, must meet drinking water standards. A copious supply for washing purposes is particularly necessary in the milk room or house.

## Methods and Equipment

Immediately before milking, the flanks, udders, and teats of the cow should be washed first with clean water, then with a chlorine solution of 100 ppm. strength, and wiped dry. Quaternary ammonium compounds may be substituted for chlorine if desired. The hair on the flanks, udders, and brush of the tail should be kept short. All milking should be done in the milking stable or dairy house.

Hand milking is commonly used. The hands must be free from open wounds and just prior to milking be washed thoroughly with warm water and soap, rinsed in an approved bactericidal solution and dried with a clean cloth or paper towel. Convenient hand washing facilities must be provided in the barn or milk house. If milking is interrupted, the milker must wash his hands again before resuming milking. Wet milking (moistening the hands with milk prior to milking) is insanitary and a source of bacterial infection and should be prohibited. Clean coveralls should be furnished milkers to prevent contamination from soiled work clothes.

Any abnormal milk should be discarded. A good practice is the use of a strip cup on each cow once a week. The strip cup consists of a metal cup in the top of which a fine wire screen is placed. Abnormalities in the milk, particularly those caused by mastitis, are shown by stringy or flaky deposits collecting on the strainer when the first few squirts of milk are directed into the cup. Another good practice is to collect the first few streams of milk from each teat in a fore-milk pail. This milk should not be added to the milk intended for human consumption. It should be observed for any signs of abnormal composition.

Milking stools should be kept clean so that the milkers' hands will not be soiled when moving the stools from cow to cow. Many control authorities pay particular attention to the stools on the theory that their condition is a good indication of general cleanliness in the barn and milk stable.

Many dairy farms use milking machines. These are suction devices connected by rubber tubing to a closed pail into which the milk is drawn from the cow through a teat cup. These machines are convenient for labor saving but are often the source of contamination because of negligence in their cleaning, spreading infection in the herd or giving rise to high bacterial counts in the milk. Operators frequently fail to realize that the rubber tubes, rubber cup linings and pail parts need more than a cursory rinse once a day.

## Cooling

Immediately after a pailful of milk is drawn it should be taken to the dairy house and strained. This is only a safety measure for removing the

TABLE 3

*Bacterial Count in Milk After Standing*

| Temperature °F. | Hours Held 24 | 48 | 96 | 168 |
|---|---|---|---|---|
| 32 | 30,000 | 27,000 | 24,000 | 19,000 |
| 36 | 38,000 | 56,000 | 4,300,000 | 38,000,000 |
| 42 | 43,000 | 210,000 | 5,760,000 | |
| 50 | 89,000 | 1,940,000 | | |
| 55 | 187,000 | 38,000,000 | | |
| 60 | 900,000 | 168,000,000 | | |
| 68 | 4,000,000 | 25,000,000,000 | | |
| 86 | 14,000,000 | | | |
| 94 | 25,000,000 | | | |

Roberts, H. O. Jr., Refrig. Eng., **42:** 306 (1941).

occasional particles of straw or hair which may accidentally fall into the milk and should not be tolerated as a means of removing the tell-tale signs of careless and dirty milking practices. Fresh, clean, sterile strainer cloths should be used on strainers of sanitary construction; otherwise they may contribute a gross bacterial contamination. The strainer and strainer pads should be kept in the milk house. Strainers should be stamped out of a single metal plate, so that there are no seams to catch and hold milk residues, and should not be made of wire mesh sieve because of the difficulty in cleaning. Demountable wire springs are provided for clamping the fresh cotton pads to the frame.

Milk should be cooled immediately after it is strained. A temperature of 60°F. will retard bacterial growth, but 50° F. or lower, a requirement for milk to be sold raw, is a practical and effective temperature for getting the best results. This is illustrated in Table 3.

When the milk is to be delivered to a plant which is more than several

hours distant from the farm, it is necessary to cool both the evening and morning milks. However, if the plant is in sufficient proximity to the farm for the morning delivery by 8 o'clock, some health departments waive the requirement of cooling morning milk because of the effective refrigeration which will be accorded it when delivered at the receiving station.[10, 12, 15]

Sufficient cooling equipment should be maintained by the diaryman to meet the needs of the maximum milking season. This reserve cooling equipment is economical since it assures proper cooling at all times and eliminates loss from bacterial spoilage with possible rejection because of high milk temperature or bacterial counts.

Cooling equipment on dairy farms takes two general forms, namely, cooling boxes (or tanks) and surface coolers. Sometimes both are used. In principle a cooling box consists of a tank large enough to hold all the cans of milk accumulated during the day, and deep enough to allow water to cover the shoulder of the can just up to the neck. The water in the tank is kept cold either by artificial cooling or by the natural circulation of cold spring water. The box must have a shelf or raised platform in the bottom so that cans of all sizes used by the producer can be submerged to the neck for cool storage. A box kept cold by the constant flow of spring water, is often called a spring box.

When such a source of cold water is not available, it is customary to build an insulated box or tank of concrete, wood, or metal.

The water is kept cold by ice or by recirculation through a refrigeration machine. Frequent cleaning is necessary to prevent the water from becoming foul. The milk is cooled by setting the cans in the box of cold water and pouring the strained contents of the pails into them, vigorously stirring the contents with each addition. A can of milk can be cooled to 50° F. in this manner in about one half hour.

The most effective method of cooling is the surface cooler. There are several different types of coolers but the one in most general use is called a washboard or surface cooler by virtue of its resemblance to an ordinary washboard. See Figure 19. It consists of a series of horizontal corrugations or pipes in a vertical frame with a perforated trough over the top and a catch basin or trough at the bottom. Cold water circulates through the inside of the pipes. Warm milk is poured into the top trough through the perforations, down over the corrugated cooled surface of the cooler, into the draw-off trough at the bottom. Any piece of equipment of this sort must be kept scrupulously clean to prevent contamination of the fresh milk.

Every dairy house should have a thermometer. This enables the producer to determine whether he has cooled the milk to the required temperature.

Milk is usually transported in the milk can from the farm to a receiving

station. Many farmers use the services of a contractor to haul the milk. Sometimes the truck is late and in summer the milk stands exposed to the direct rays of the sun and consequently rises in temperature; in winter the milk may freeze. A small covered platform should be provided as a collection station to protect the milk from the weather and to provide pro-

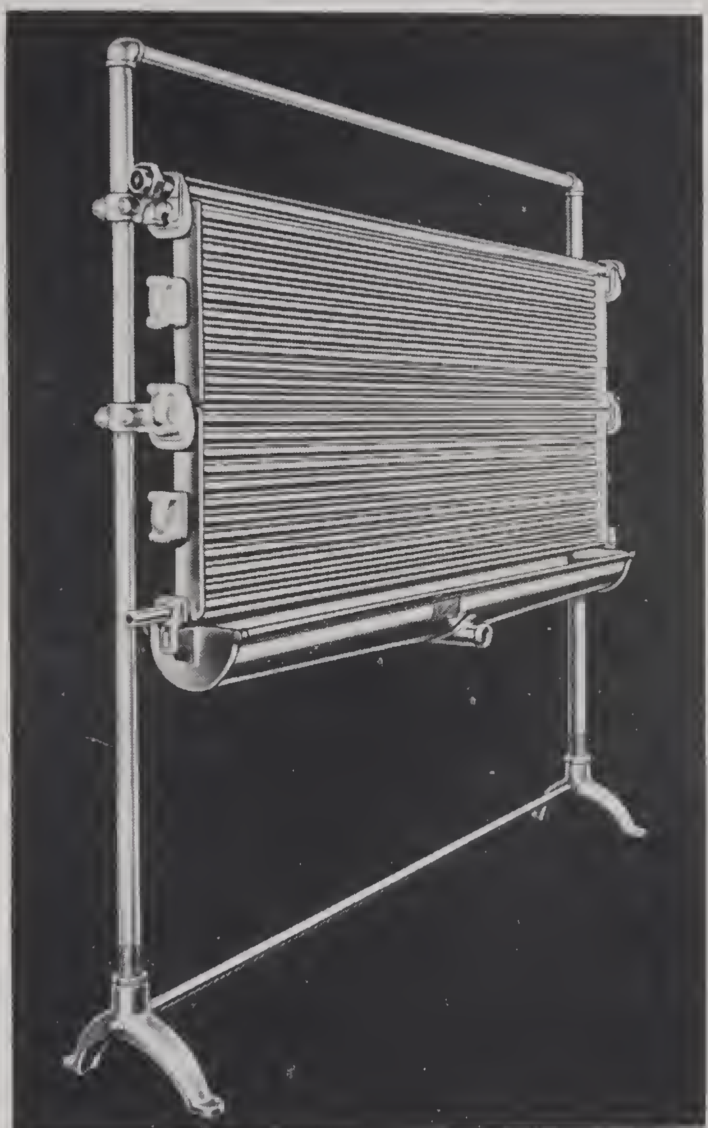

FIG. 19. Surface type milk cooler. (Courtesy, Creamery Package Co.)

tection for the returned clean cans. The trucks should have closed bodies to protect the can from dirt and sun.

## Cleaning Utensils

All utensils or equipment must be made of smooth non-absorbent material and constructed so that they are readily cleansed. All joints or seams should be welded or soldered flush with the metal. Utensils should be kept in good repair.

The milk house should be equipped with an adequate supply of fresh

cold water and also with hot water or steam for use in washing utensils and equipment. "Wash-up" operations preferably should not take place in the same room where the milk is strained and cooled. The cleansing of equipment is a dirty messy operation and may contaminate the clean milk in storage. Vats with at least two compartments, each large enough to handle any piece of equipment, must be provided for washing the utensils. Sterilization in the form of a chlorine or a similar kind of solution should be provided. A drain rack is also desirable.

Unclean dairy equipment is one of the important sources of microbial contamination of milk. Micro-organisms multiply rapidly on the surfaces of dairy utensils which are milk-wet from previous use. Cleanliness to the eye is not sufficient. A small residual contamination will afford sufficient nourishment for bacterial growth in enormous numbers, and grossly contaminate succeeding portions of milk. It is very important to cleanse the utensils immediately after use in order to remove all nutrient materials for bacterial growth, and to prevent drying of milk residues. If utensils or other milk equipment smell "milky" they are unclean—tinned iron has no odor.

The first step is to rinse the equipment with clean cold or lukewarm water. If hot water is used, the milk residues may be coagulated, or cooked onto the surfaces with attendant difficulty in removal. Another advantage of the pre-rinse is that it removes the excess milk, avoiding pollution of the wash water with these residues. Dirty wash water not only fails to cleanse the equipment by leaving a film of dirt, but it also weakens the detergent.

After rinsing, the utensils should then be scrubbed in a good alkaline detergent. This may consist of sodium carbonate, trisodium phosphate, or mixtures of these with other chemicals to soften the water or to reduce the corrosive action on the metal. *Soap should never be used.* It leaves a film which is difficult to remove and protects the entrapped viable organisms from bacterial treatment. The water should be as hot as the hands will bear. The amount of the detergent will vary with its composition and the hardness of the water. A sufficient amount should be used to remove grease effectively. The utensils should be immersed in the detergent solution and scrubbed with a stiff brush. A wash-rag should not be used. After thorough washing, the utensils must be rinsed in clean, warm or preferably hot, water.

The bactericidal treatment of the cans, strainer, pails, cooler, stirrer, and other equipment may consist of the use of steam or chlorine as the disinfectant. Some municipalities require that the equipment be placed in a cabinet and thoroughly steamed. Others require thorough scalding. The most effective treatment is to place all equipment in large autoclaves and sterilize them under steam pressure. When utensils are scalded by

immersion in hot water, a relatively large amount of water is necessary. The practice of pouring scalding water from a tea-kettle into a milk vessel, rinsing the inside, then pouring this water into the next utensil, and so on repeatedly, is no better than a poor rinse, because the water cools rapidly and soon loses what little bactericidal effect it had.

When chlorine, usually in the form of hypochlorite, is used as the bactericidal agent, the utensils must be given a good rinse with clean water so that all foreign matter or dirt is removed, since organic matter combines with the chlorine, whether it be in the form of bacteria or residues of milk or particles of stable dust, reducing the amount of disinfectant available for action on bacteria. Chlorine solution for equipment sterilization should contain about 200 parts of chlorine per million parts of water. It is usually made up from "chloride of lime" or from various commercial preparations of chlorine.[9] Other disinfectants may be used in accordance with methods that have been found to give satisfactory results.

Several methods are advocated for cleansing milking machines. Since there may be specific state laws or recommended procedures of state or local health departments no single method can be recommended for every locality. In general any method adopted should include physical cleaning of the entire apparatus followed by some bactericidal treatment. Between milkings the machine and its appurtenances should be stored in such a way that contamination will be prevented. The whole system should be subjected to a bactericidal flushing, just prior to re-use.

The physical cleaning should start by drawing through the milking machine 3 to 4 gallons of tepid water. This rinses out any remaining milk. The machine should then be disassembled and all parts brushed with clean stiff brushes to remove any adhering milk particles. The type of bacteriological treatment may be one of several. Use of water at 180° F. sucked through the milker is accepted in some areas. A chlorine or other suitable disinfectant solution can be used. A lye solution, 0.4 to 0.5 per cent in strength, is also used. When the hot water rinse is used, the teat cups and rubber tubes are usually stored in a dry protected place. Should lye be used a hot rinse (180° F.) usually precedes it; the cups and tubes are then filled with the lye solution and left until the machine is to be used again, when the solution is rinsed out. Lye solutions corrode aluminum, a metal commonly found in milking machines. The machines should be disassembled for cleaning at least once a week.

After sterilization utensils must be stored in such a manner that they are protected from contamination by dust or dirt. Paper strainer discs must be kept in the original package and handled in a manner that will keep their surfaces sterile.

### Personnel

It is important that anyone having a part to play in the production of milk be free from any communicable disease and from contact with persons having such diseases. Enforcement of regulations of this effect is difficult because of the slowness with which notices or reports of communicable disease may reach the health department. Often by the time the quarantine is established and the involved milk dealer notified, the communicable stage of the disease has passed. Occasions have been known where the patient had recovered sufficiently to return to work by the time quarantine regulations were instituted by the health department. This places a serious responsibility of self-regulation on the dairy farmer and demonstrates the importance of educational methods.

A physical examination upon employment, similar to that required for food handlers, should be given all new employees. Particular attention should be noted of any history of illness that might indicate a typhoid or paratyphoid carrier. Milk handlers should be carefully observed each day for evidence of illness and if showing signs of infection be relieved immediately from work which involves handling the milk or equipment.

## MILK PLANTS

These may be small country receiving stations or large pasteurizing establishments. The country receiving station usually owned by an urban milk producer is a local point for the collection of milk from nearby farmers. Upon receipt at the station the milk is checked for taste or odor, tested for sediment, and samples for butterfat content and bacterial counts are taken. The milk is weighed and then passed into chilled tanks. Milk is commonly transported in glass lined trucks or railroad cars to the urban pasteurization plants which frequently cover a milk shed of 300 miles. Milk is purchased on the basis of butterfat content and sanitary quality as shown by tests.

Milk cans are washed, sterilized, and dried before being returned to the farm. Mechanical can washers are generally used in these stations. They vary in size and type in relation to the number of cans cleaned per hour. These washers utilize the basic detergent principles previously discussed for farm utensil cleaning.

## PASTEURIZATION

"Pasteurization is the only public health measure which, if properly applied, will adequately protect against all infectious milk-borne disease organisms which may have entered the milk prior to pasteurization."[8]

A law established by Denmark in 1898, requiring the heating of all milk

to a temperature of 185° F. before being fed to calves as a means of preventing bovine tuberculosis infection, was the forerunner of commercial milk pasteurization. By 1907 the first commercial plant pasteurization apparatus was installed in New York City.[2] At least 5 states, 18 counties, and 870 municipalities in the United States now require that market milk be pasteurized. Of these only 349 municipalities exempt certified milk from the pasteurization requirement.[25]

Careful tests in laboratory and commercial milk plants confirmed by the experience of many years have shown that the heating of milk to a tempera-

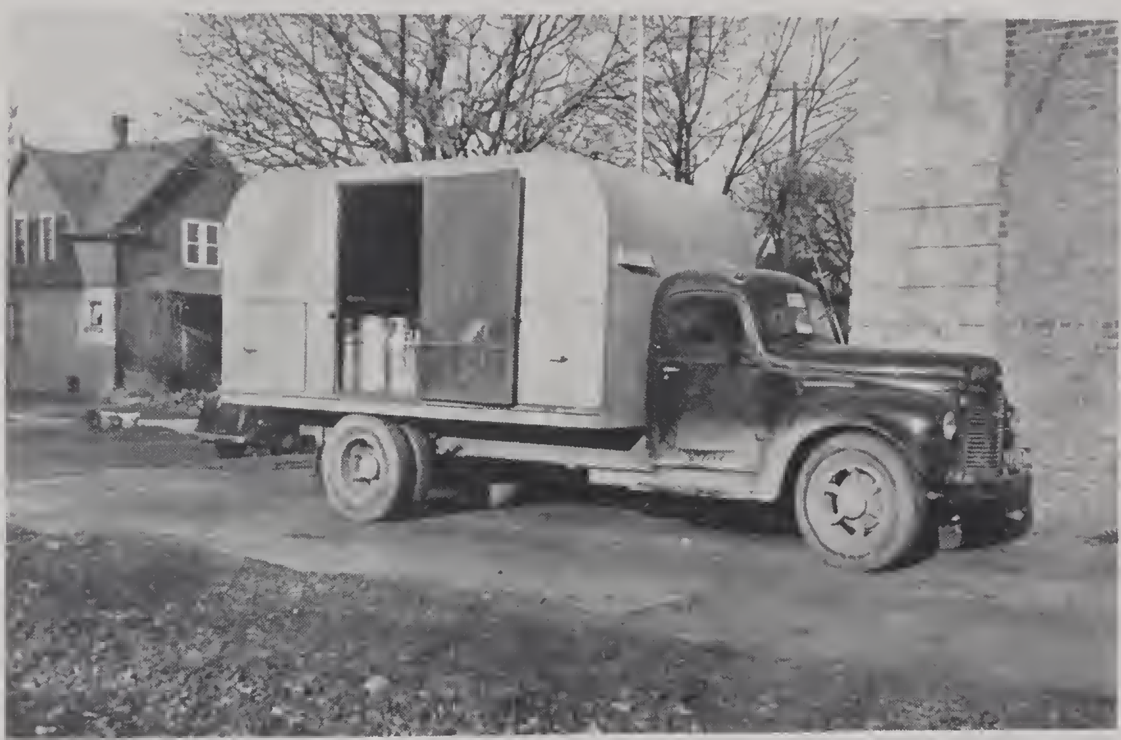

Fig. 20. Insulated truck for the transportation of milk. (Courtesy, H. S. Adams, "Milk and Food Sanitation Practice", p. 17.)

ture of 143° F. for 30 minutes makes it safe from pathogenic bacteria. The high temperature-short time method of pasteurization is used in many plants handling large volumes of milk. This process employs a temperature of 161°F. for 15 seconds.

Pasteurization is the principal safeguard between a contaminated milk supply and the public. For this reason a high degree of skill and conscientiousness is required of all personnel. Methods must be dependable, equipment be constructed of material and of a type that permits easy and effective cleaning, with adequate precautions taken to detect and avert faulty operational procedures.

The steps of treatment in pasteurizing are:

a. Receipt at the pasteurizing plant where the cans of milk are poured

into a weighing tank. From this tank the milk flows by gravity to a dump tank.

b. From the dump tank the milk goes to milk pumps and then through a milk filter or clarifier to holding tanks or directly to pasteurizers.

c. The milk next goes from the pasteurizer to the cooler.

d. From the cooler it is sent to the bottle-filler and thence to cold storage rooms or to trucks for immediate distribution.

When the milk is received at the pasteurization plant it is poured into a weigh tank. At the same time the underside of the can cover is sniffed immediately after it is taken off the can to check on any undesirable odors. Feeling the outside of milk cans gives a rough check of temperature control. Samples of the milk for determining butterfat content and bacteriological counts are also taken. The bacteriological samples may be taken to a laboratory for plating or direct counts from smears may be made right on the platform at the time of sampling. The weighing operation is required by the producer since farmers are compensated on the basis of total butterfat content; this particular step is not required for public health reasons.

The empty cans are passed through a can washing operation where they are carefully cleansed and "sterilized".

The milk flows from the weigh tanks, usually by gravity, to milk pumps which force the milk through filters for the purpose of removing any dirt. These filters are made by stretching filter cloth over circular or flat metallic screens. They are usually located before the regenerator or between it and the pasteurizer. Extraneous material may also be removed by centrifugal separation in power-driven machines called clarifiers. When centrifugal clarifiers or separators are used they are installed to receive milk directly from the dump tank; they discharge to the milk pump.

From the clarifier the milk may flow to cooled tanks for holding or it may be run directly into a pasteurizing unit. The route taken depends upon the operation in the plant at the time.

The high temperature-short time method (161° F. for 15 seconds) has replaced the 30 minute holding method in some areas. For either method, a good supply of steam is required. A plate type of pasteurizer is in common use (Figure 21). This consists of a series of plates so formed and arranged that milk can flow through the plates in one channel and the heating medium flow in the opposite direction in another channel. The space between alternate plates provides passage for the flow of the milk. In between these plates is the circulation system used for the steam or hot water. The plates are mounted between two terminal heads, presenting something in appearance like a filter press. The pressure in the pasteurized

milk system should be higher than that in the heating fluid to prevent contamination of the milk by the heating medium, should a leak develop between the two systems. Pathogens are destroyed as effectively by this method as by the 30 minute method but thermophilic bacteria may be difficult to control.[3, 9, 19, 20]

Another important part of the new type pasteurizer is the control system that will prevent any improperly or inadequately pasteurized milk from entering the pasteurized milk supply. Two methods can be used, both based on temperature controls. One is the flow diversion valve which will

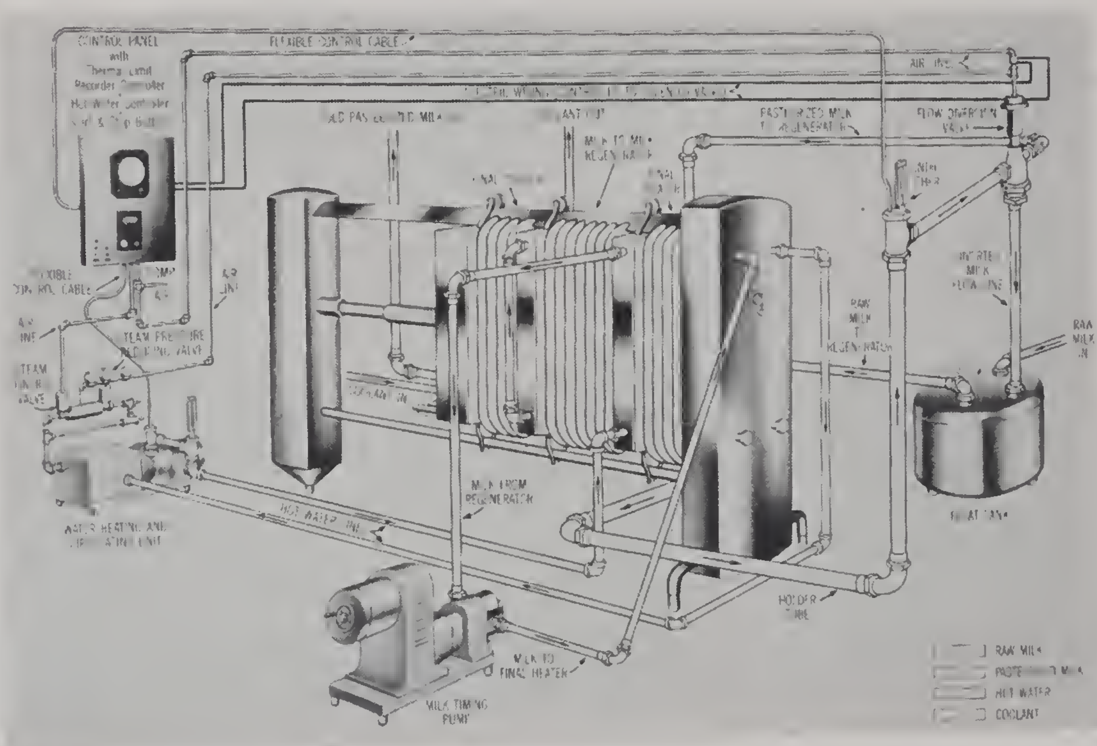


FIG. 21. Outline of the high temperature milk pasteurization process. (Courtesy, Creamery Package Co.)

pass the milk coming from the pasteurized side of the unit back into the raw milk entrance if the temperature drops below a certain level while milk pump stops serve the same purpose by ceasing operation if the temperature drops below the pasteurizing point.

Individual tanks for the holding method of pasteurization are also available. These consist of a receptacle, usually of stainless steel, in which the milk is heated. Surrounding this vat is a jacket through which the heating medium circulates. A solid cover, overhanging the pasteurizer vat and sloping downward from the center, protects the milk during pasteurization. Either steam or hot water can be used in the jacket. Hot water can circulate continuously in the jacket or else it can be sprayed in a film around the top of the jacket. The water runs out at the bottom and is

recirculated through the hot-water boiler where it is heated to the proper temperature before entering the pasteurizer again.

Some means of agitating the milk should be installed in each holding vat. This usually consists of a paddle or vane on a vertical shaft that slowly revolves, keeping the milk in constant movement. This step is necessary to assure thorough heating of all of the milk. The space between the milk surface and the vat cover must also be heated. Agitating the milk will

FIG. 22. Multiple-process holding pasteurizers, Heathwood Farms, Lansing, Mich. (Courtesy, Creamery Package Co.)

form a certain amount of foam, and unless these bubbles are specially heated they will become cooled from the vat cover and serve as an insulating layer to the milk in the vat preventing some of the milk from being completely pasteurized. A frequent method of air space heating is the introduction of live, dry steam into the air space in sufficient quantity to keep the temperature at 148° F.

After pasteurization the milk is quickly cooled to about 45° F. This is accomplished by the use of a surface cooler similar in type to that used on the farm, page 83. Jacketed tubular coolers with the outer shell carrying the cooling solution are also used. This equipment is more difficult to clean

than surface coolers and for this reason is not as popular. Ice water, brine or direct expansion ammonia, freon or sulfur dioxide are used as cooling media. A recording or indicating thermometer is installed in the discharge from the cooler, so that control and proper cooling is possible. Exposed surface coolers introduce a chance for airborne contamination, so requirements of operation should include the location of the cooler in a separate room used for no other purpose, or else coverage with a removable and cleanable shield.

The present-day pasteurizers are built to conserve energy by an interchange of temperatures between the cold raw milk and the hot pasteurized milk. As the hot milk leaves the pasteurizer it passes through plates or coils that are jacketed by the cold raw milk flowing to the pasteurizer. The cold raw milk cools the hot pasteurized milk appreciably while at the same time heat is received in the cooling process. During this regeneration process the raw milk will be raised from 40° F. to as much as 120° F. and the hot pasteurized milk cooled from 142° F. to 62° F. A similar interchange of temperatures is possible on the high temperature-short time pasteurizers.

A separate cooling unit for cooling the pasteurized milk to the required temperature can be installed in the regenerator.

## Temperature Control

The temperature margin between destruction of the resistant tubercle organisms and impairment of the organoleptic (taste and appearance) quality of the milk is relatively narrow, from 140° F. to 145° F. for an extended period of time. Health considerations, allowing a margin of safety, preclude a pasteurization temperature below 142° F. and commercial considerations preclude a treatment above about 145° F. In order to hold the temperature between these limits, it has been necessary to provide accurate thermostatic control. In addition, health department regulations require that a permanent record of the temperature and elapsed time be maintained for any pasteurization period. Thermometers are fastened to rotating drums of clock-like mechanisms which are usually made to complete one rotation in 12 hours. The charts are graduated to coincide with the speed of the clock. The temperature of the milk is transmitted through a bulb fitting to the recording chart in the pasteurizer by means of a liquid in a flexible metallic tube. This temperature record is not so accurate as the indicating thermometer, and the past plant pasteurizing performance is gauged by correcting the recording thermometer readings according to the temperature shown on the indicating thermometer, when both thermometers are inserted in a liquid of uniform temperature.

A correct temperature control and period of service of the hand-operated single vat pasteurizer is easily determined by reading the temperature from the indicating thermometer and noting on the recording temperature chart the length of time, in addition to the regulation thirty minute period, required for filling the tank beyond the level of the recording thermometer bulb. It is obvious that the temperature curve will register pasteurization levels as soon as the level of the incoming milk reaches the bulb. The thirty minute holding time must be gauged from the time the last milk enters the vat (if the milk is heated outside the vat) to the time it begins to discharge. Where the milk is heated in the vat, the indicating thermometer and the recording temperature chart show the heat treatment, provided no milk is added after the maximum temperature has been reached.

The continuous type of pasteurizer always provides for heating the milk outside the pasteurizer tubes, pockets or tanks. The recording temperature chart registers only a continuous line at the pasteurizing temperature level because the bulb is continuously immersed in the milk at this temperature. The correctness of the timing treatment in a tubular pasteurizer is estimated by introducing some easily determinable product in the milk as it enters the holding device and then reading from a watch the length of time which elapses before the product appears at the outlet end of the holder. The indicating substances most generally used are chloramine, uranine, starch iodide, and the test organism *Bacillus prodigiosus*. The permanence of the adjustment is assured by gearing the pump to a motor of reasonably constant speed.

Accurate indicating thermometers should be used frequently to check the temperature in the milk as received at the platform, maintained in the storage tanks, developed in the pasteurizers, cooled by the post-pasteurization coolers, and in the storage rooms. Recording thermometers should be checked frequently against indicating thermometers and adjusted accordingly.

**Tests for Under-Pasteurization.** Several laboratory tests have been developed to determine whether milk or cream has been effectively pasteurized. The most satisfactory and widely used of these is based on the sensitivity of the enzyme monophosphoesterase to the destructive effects of heat near the pasteurization temperature. About 96 per cent of the enzyme in raw milk is destroyed by heating at 143° F. for 30 minutes. Very slight deviations in temperature or holding-time can be detected. Contamination of properly pasteurized milk with such small amounts of raw milk as 0.5 per cent are easily determinable. The test is based on the property of the normal enzyme to liberate phenol from a solution of di-

sodium phenyl phosphate. The phenol is colored blue by the addition of 2,6 dibromoquinonechloroimide, the intensity is measured colorimetrically, and the efficiency of pasteurization determined by the color. Page 76.

In rare instances false indications of under-pasteurization have been noted when this test has been used. This has been caused by the presence of *Lactobacillus enzymothermophlus*, a heat resistant organism.[5] So that laboratory results are not misinterpreted, all samples indicating under-

Fig. 23. Milk bottle washer, Roelof Dairy, Galesburg, Mich. (Courtesy, Creamery Package Co.)

pasteurization should be repasteurized in the laboratory to prove infection of heat resistant organisms.[14] Caution must be used in applying this test to chocolate drink or to cream separated after pasteurization.

## Bottle Fillers

A covered conveyor belt is employed to carry clean bottles from the washers to the automatic filling machine. This machine fills the bottles to constant levels. The milk in the bowl is protected from the entry of foreign material by a cover. Adjacent to the filler is the automatic capping machine. This machine places a cardboard disc (or milk cap) from the tube onto each bottle as it passes and presses it into the cap seat. All of these oper-

ations are performed automatically without any manual contacts. Occasionally a cap is not seated correctly or a bottle may not be properly filled. Such bottles should be set aside at once. No attempt should be made to complete the fill or to adjust the seating of the cap by hand. Milk bottle caps or single service containers, when used, should be purchased in their original cartons and stored in a dry place.

### Storage

After bottling, the milk is immediately conveyed to the storage rooms. The temperature here is maintained between 35° and 40° F. As a matter of fact the temperature fluctuates rather widely when new batches are put in or removed. When stored, the cases of bottled milk should not be piled in compact stacks, but aisles should be left to facilitate cold air circulation.

### Bottle Washers

Proper cleansing and bactericidal treatment of bottles before filling is a critical step in milk production, whether it is a pasteurized or raw milk supply. The most effective and economical bottle washers are the power driven, soaker type machines illustrated in Fig. 23. Dirty bottles are fed into the machine on an endless conveyor which carries them through several compartments containing an alkaline detergent of from 2 to 4 percent strength. The temperature of the solution in each compartment becomes progressively higher up to a maximum of about 140° F. to 160° F. and is then gradually lowered in subsequent compartments. A fresh water rinse, followed in some installations by a chlorine solution rinse, results in the delivery of a practically sterile bottle. The importance of clean bottles can not be overemphasized.

### Paper Containers

The great bulk of the retail milk supply is packaged in pint or quart glass bottles. The availability of these to the general public and their convenient shape has led to their use for all sorts of purposes by the consumer. This abuse has constituted a great expense to the milk dealers on account of the loss of bottles from distribution, in addition to the necessity for installing expensive bottle washing machinery. To circumvent these abuses and expenses, some milk producers turned to the use of paper or cardboard containers for milk. Subsequent use has indicated other advantages over the glass bottle.

The use of paper cartons to replace glass bottles was instituted in Los Angeles, Calif., in 1908 and it is estimated that by 1949 some 5 billion were in daily use in the United States. They are as sanitary, by bacterial testing, as the glass bottle. Generally they are used on wholesale routes and for supplies to stores and restaurants. The containers can be pur-

chased pre-fabricated, shipped in tight, sanitary cartons. Large pasteurizing plants manufacture their containers on the premises, providing a continuous movement from paper stock to formed containers, paraffining, and, finally, to the bottle filler. The same precautions taken in handling glass bottles must be observed in the use of paper containers.

## Construction of Equipment and Buildings

Milk handling equipment in general and milk pasteurization equipment in particular must be constructed so that all parts are readily accessible for cleaning. All pipes and connections must be completely and easily dismountable. The surfaces of pipes, pumps, walls of tanks, filters, cans, and any other equipment must be smooth and easily cleaned. They should be constructed of material that is not appreciably attacked by milk or by the chemicals used in cleaning them. Glass or enamel lined equipment has not held the favor it once possessed because of the chipping of the coating leaving bare iron exposed. Cracks in the enamel preclude effective removal of milk residues and become bacterial contamination foci. Stainless steels are resistant to the corrosive action of milk and cleaning agents, take a high polish, present a pleasing appearance, and are generally used in the construction of milk plant equipment.

Only "sanitary piping" should be used. This designation is used for pipe that:

a. Is made of or is heavily coated with non-corrodible smooth material;

b. Is large enough so that all pipe, fittings, and connections can be cleaned readily with a brush;

c. Is of such size and shape that it can be inspected to determine its cleanliness. In general, a diameter of $1\frac{1}{2}$ inches should be the minimum used. The lengths of pipe should be short to facilitate cleaning;

d. Is free of any sharp bends or any other condition including dents that would make it difficult to clean.

All valves on the inlet and outlet sides of pasteurizing units should be of the leak protector type. These valves have a channel cut in the valve plug so that if milk leaks into the valve it will be diverted to waste through the channel rather than allowed to enter the pasteurizing vat from the inlet side or the discharge line on the outlet side. Should either kind of leakage occur, it will introduce incompletely pasteurized milk to the rest of the batch.

The building interiors must be adequately lighted and ventilated. Satisfactory natural lighting means an even distribution from windows and sky-lights equal in area to at least 10 per cent of the floor area. Floors, ceilings and walls must be of an impervious material. Concrete or tile is most satisfactory. Any construction that makes thorough cleaning difficult or that hides poor cleaning should be avoided.

## Cleaning Operations

The proper and effective cleaning of dairy plant equipment requires detailed care. If any traces of milk are left in the equipment, there will be a growth of bacteria which infects succeeding batches of milk. Cracks, crevices, pockets, dead ends of pipes, broken insulation covering, exposed threads or connections and inaccessible parts of the machinery, all afford opportunity for small amounts of milk to accumulate. Spilled milk may seep into cracks in the floor, spread under machinery, or soak into packing or insulation of equipment, where it spoils with attendant odor. A clean milk plant does not smell "milky". Clean equipment does not feel greasy.

If milk is not properly removed from equipment before hot water is applied, if hard water is used for washing, or if the proper detergents are not used, a porous, hard coating of a mixture of milk solids and salts insoluble in water accumulates on the equipment. This is called milk stone. It insulates the equipment from effective cleaning and sterilization and harbors a type of bacteria which is heat resistant.

Milk apparatus should first be rinsed with lukewarm water which removes most of the residues. Then all piping should be taken down, the equipment dismantled, and all parts thoroughly scrubbed with a stiff brush and a detergent solution. A solution such as one-half of one per cent trisodium phosphate or mixtures of this salt with carbonate or metasilicate or other chemicals are non-scale forming in water. A wash trough 12 inches deep and 12 inches wide and long enough to accommodate the greatest length of pipe, must be provided. After the equipment has been cleansed it should be thoroughly rinsed with clean water and reassembled and then steamed for about 5 minutes from the time the steam discharged from the piping reaches 200° F. A substitute for the steam is the use of a chlorine solution with a strength of from 100 to 200 ppm. The standards of cleanliness and personal hygiene previously discussed for milk handlers on the farm, on page 87, also apply to the milk plant.

Adequate toilet facilities must be provided in convenient locations. They must be kept clean and the disposal of the sewage must be by satisfactory methods. Hot and cold water, soap and towels, must be provided in conveniently placed lavatories. The personal hygiene of the dairy workers must be as good as that already discussed for food handlers.

## Raw Milk Production

There is no public health reason for the sale of raw milk. Pasteurized milk can be provided if the community insists upon it. There are many public health reasons why raw milk should not be sold.

The requirements for raw milk production frequently are stricter than those for milk to be pasteurized. Bacterial counts must be lower. Even

these precuations, though, cannot guarantee a safe supply. In general, the same requirements for dairy barns, milk houses, water supply, sewage disposal, and insect and rodent control already discussed apply equally to farms producing milk for pasteurization or milk to be sold raw. The milk handling operations must be performed in a room separated from the utensil washing operations. Automatic filling of bottles must be used and mechanical capping should be required.

Raw milk operations are frequently small businesses. This may permit the advantages of owner participation in all activities. Frequently, due to economic considerations it means that proper plant and equipment cannot be purchased.

### Milk Delivery

Cases of milk packed on the delivery wagons for retail distribution should be protected from excessive heat in the summer and from freezing in the winter. The former is accomplished by protecting the milk from direct exposure to the sun, and by keeping the bottles covered with cracked ice. The temperature of the milk in the bottle should not exceed 50° F. In winter the wagon should be kept closed and when necessary be slightly warmed. Although the milk bottles are tightly capped (and often hooded) this protection does not excuse dirty transportation and delivery practices. The bottle contaminated by handling or by miscellaneous street dirt may lead to contamination not only of the milk but also of other foods in the kitchen. Cleanliness contributes to the safety of the milk and at the same time attracts consumer acceptance.

## DAIRY PRODUCTS

Milk is a food especially well adapted to processing and canning. Evaporated milk, condensed milk, and condensed skimmed milk are canned commercially in large quantities. The United States Department of Agriculture has defined evaporated milk as containing not less than 7.9 per cent of fat and not less than 25.9 per cent of milk solids; condensed milk as containing not less than 8.0 per cent of fat and not less than 28.0 per cent of milk solids; and condensed skimmed milk as containing not less than 24.0 per cent of milk solids not fat.

### Homogenized Milk

Homogenization is accomplished by pumping pasteurized milk, before cooling, through a device that breaks the normal butter fat globules into fine particles about 2 microns in diameter. In practice the milk is pumped at a pressure of 2500 to 4000 or more pounds per square inch through small orifices. The fat globules are sheared or shattered into smaller particles.

## Condensed Milk

Commercial manufacture of condensed milk was developed by Gail Borden in 1856. His original process concentrated milk in a vacuum. It was soon discovered that the keeping qualities of the milk were enhanced by the addition of 42 per cent of sugar. Only market milk grade is used. After cooling to 40° F. in the holding tank the milk is introduced into a foreheater and rapidly heated to 206° F. to destroy bacteria and dissolve the sugar. It is then transferred to vacuum pans at 145° F. and concentrated to 40 per cent of original volume. Following condensation the milk is cooled in tubular coolers to 70° F. Cans are filled by automatic fillers, and then sealed and released for sale.[21]

## Evaporated Milk

Unsweetened evaporated milk was developed in Switzerland about 1884 by John B. Meyenberg. In this process 60 per cent of the water is removed by vacuum heating at 135° F. The concentrated milk is homogenized, cooled, and canned using automatic filling machines. The sealed cans are processed by sterilization at 245° F. for 30 minutes.[13]

## Dried Milk

The use of dried milk has been known for centuries.[6] Whole malted milk developed by William Horlick in 1883 was the first successful commercial type. Sam Percy developed the spray process in 1872. In this process milk and hot air are forced through nozzles into a chamber at 180° F. with complete loss of liquid. The resulting powder is collected from the floor of the dryer.[13] Heated drum dryers are also used in which the milk is pasteurized prior to drying. After drying, the powdered milk is ground, if necessary, sifted and packed for individual consumer use. Most dried milk is of non-fat solids composition. It is used extensively in ice cream, bakeries and cheese products, confections, dried soups and prepared meats.

### *Processing Plants*

As a rule, milk is concentrated and canned at plants located in small towns or in the country close to the source of supply. It is usually gathered by truck or delivered by the farmer to the plant. The standards for raw milk for processing should be no less stringent than are those for raw market milk, and the use of any milk which has started to ferment and sour should not be tolerated. Milk delivered to the plant is tested first for flavor and odor, and then for acidity to detect excessive souring and to determine the amount of phosphate or other neutralizing material which may be required to permit further handling. Excess acidity soon leads to coagu-

lation. Off flavors or odors should be thoroughly investigated before the milk is accepted.

Good sanitation within the plant is especially important. All pipe lines, tanks, pumps, etc., should be rinsed and flushed with very hot water daily. The equipment should be dismantled and thoroughly cleaned each day, and after it is assembled the following day it should be rinsed again with hot water before use. Windows in the milk plant must be kept well screened and the plant kept free from insect and rodent infestations. Controlled use of insecticides should be practiced. Page 79. Other sanitation procedures that apply to the milk plant, page 87, must be observed in milk concentrating and drying plants.

## Chocolate Drink

Chocolate milk drink is a popular beverage, especially in summer. It is made according to a wide variety of formulae. The Baltimore City Department of Health initially set the composition standards, namely, that the butterfat content shall not be less than 2.5 per cent, the cocoa shall not exceed 5 per cent, and the sugar shall not exceed 6 per cent. Other health departments have adopted various standards. The milk must be pasteurized and handled with all the sanitary care accorded the regular milk supply. Cocoa has a tendency to settle out and form a more or less compact layer in the bottom of the bottle, which is difficult to resuspend. Numerous so-called stabilizers, emulsifiers, or suspending agents, are added to the formulae to keep the cocoa uniformly in suspension. These are usually gum-like or colloidal substances of vegetable origin. Chocolate drinks, containing little or no milk, are usually not approved for consumption by children because of the poor nutritional quality and the fact that the intake of milk is usually reduced.

## Fermented Milk

This class of milk specialties consists chiefly of buttermilk and acidophilus milk. Buttermilk originally was the skimmed or fat-free milk which was left from the churning of cream to make butter. The increasing demand for this product and the removal of butter churning from urban availability has led the dairy industry to make a so-called cultured buttermilk. This is made by inoculating pasteurized skimmed milk with pure lactic acid cultures, similar to those used in culturing cream for churning into butter, and incubating the batches until the desired acidity is obtained. This gives a product of constant quality. Sometimes a small amount of cream is added and the whole batch churned until the butter granules just begin to form.

Acidophilus milk is made by inoculating pasteurized, practically

sterilized, skimmed milk with cultures of the organism, *Lactobacillus acidophilus.* This bacterium develops lactic acid but the accompanying bacterial metabolic products are greatly different from those produced in the making of buttermilk. Acidophilus milk is much more expensive than buttermilk because great care and costly technical supervision are required for its production. The acid content of these milks usually prevents the growth of pathogenic organisms.

### Vitamin D Milk

The enrichment of milk with Vitamin D dates from the recognition of the prevalence of rickets, faulty tooth structure, and other symptoms of inadequate calcium and phosphorus metabolism. Vitamin D occurs naturally in appreciable amounts only in the fish oils, in eggs, and to a less degree in milk.

Three general methods are used to increase the Vitamin D content of milk. The milk of cows fed irradiated yeast mixed with their feed will be increased in this vitamin content. This method is used almost exclusively for producing Vitamin D certified milk. The product is called metabolized milk. When milk is irradiated with ultra-violet light from the sun or from some special type of lamp, its content of Vitamin D is increased. This is called irradiated milk and is made by treating regular milk before pasteurization. When fish oils are treated to remove their unsaponifiable fraction, this portion is found to carry practically all the original Vitamin D. It may be added to milk to increase the Vitamin D content to the recommended level of 400 units per quart. This is known as fortified milk.

### Ice Cream

Ice cream is made of milk, cream, flavors and sugar, to which may be added color, eggs and stabilizers. Condensed, dried or evaporated skimmed milk may replace the natural product. The flavors consist of vanilla, chocolate, nuts, and fruits; these are occasionally fortified with synthetic compounds. The sugar is usually sucrose but some corn sugar is used to a limited extent. It is necessary to add coloring materials since the color of the fruit or flavor is not strong enough to overcome the whiteness of the concentrated milk solids. The colors are always those which have been certified by the United States Department of Agriculture to be safe for use in foodstuffs. The stabilizer may be gelatin or a vegetable gum. It is used to impart smoothness to ice cream by assisting in the thorough emulsification of the butter-fat in the mix and by minimizing the crystalline, icy, texture imparted by the freezing. The amount of this stabilizer is usually less than one-half of one per cent. Some brands of ice cream, high in total solid

content, are made without the addition of a foreign stabilizer. An average ice cream may have the following approximate composition:

| | |
|---|---|
| Butterfat | 12–14 percent |
| Milk solids not fat | 9–11 percent |
| Cane sugar | 14–16 percent |
| Eggs | 0.3–0.6 percent |
| Stabilizer | 0.25–0.50 percent |

The same practices and safeguards required in the production of fluid milk apply to the manufacture of ice cream. A maximum bacterial content of 100,000 organisms per gram of ice cream is generally considered to be a reasonable requirement, since good sanitary practice has shown that many plants regularly produce ice cream considerably below 10,000 organisms per gram.

### *Manufacturing*

The combination of ingredients that make ice cream is called the "mix", prior to freezing. Mix is made in sanitary vats or tanks usually glass-lined or made of stainless steel. All the ingredients except the flavors are weighed or measured into the mixing tank, thoroughly agitated, and then piped to the pasteurizers.

The pasteurization of ice cream mix follows the same general procedure as for milk. The equipment must be built of materials which do not contaminate the product with copper or iron, otherwise certain off-flavors may develop. The temperature of pasteurization should be 155° F. for 30 minutes or 175° F. for 25 seconds. These higher temperatures are necessary because the higher content of solids in mix (about 36 to 40 per cent) as compared with that of milk (about 12 to 13 per cent) exerts a slight protection against the bactericidal effect of heat. After pasteurization the mix is homogenized (page 98).

From the homogenizer the ice cream mix is cooled as in milk plants. It is then ready for freezing. Most freezing is done in so-called batch freezers which are large scale developments of the old household freezer, but are constructed on a horizontal instead of a vertical axis. They consist of a jacketed metallic cylinder in which a "dasher" rotates on the horizontal axis. Chilled brine or direct expansion ammonia circulates through the jacket. Sharp knife blades scrape the inside of the container to remove the frozen mix from the freezer wall to reduce the insulating effect it would otherwise have. An additional set of blades rotates rapidly during the freezing to whip the mix and beat air into it. A variation of the batch freezer is the continuous freezer in which the mix and a measured volume of air are pumped into the horizontal jacketed freezer cylinder where a rotating scraper moves the mix slowly forward while exerting a whipping action.

The "frozen" mix is discharged continuously from the tube under the front end of the cylinder. The fruit and nut flavors are added just before the ice cream is discharged from the freezers. The chocolate may be added before the mix is pasteurized. When chilled and whipped mix from either the batch or the continuous freezer is discharged, it has the consistency of thick cream. This is packaged and stored in the hardening room where the temperature is maintained at about 10° F. Here the product becomes hard. After hardening the ice cream is stored at −10° F. until used. Ice cream is often packaged in paper cartons for both bulk shipment and consumer use.

In all of these operations, as in milk handling, the product can be and usually is, protected from human contact at all points. However, when ice cream is served from bulk containers at the dispensing fountain or restaurant, it may become contaminated by a dirty dipper or by the dispenser. Proper restaurant sanitation can eliminate this danger.

Some ice cream stores purchase mix and freeze it in counter freezers. Unless the mix is properly handled and the freezer kept scrupulously clean a contaminated product will result. Many health departments prohibit the use of counter freezers. Where the freezers are permitted a common requirement is that the freezer be partitioned by glass panels or otherwise from the store proper. In any case, where counter freezers are permitted proper facilities for cleansing and bactericidal treatment should be demanded.

Ice cream manufacturing equipment must be kept scrupulously clean. The procedures discussed for milk plant sanitation apply also to this industry. See Page 96.

## Butter

Butter is made from sweet or sour cream and is a conglomeration of the natural butterfat. It should have a light straw color with a fresh, sweet odor. Commercial butter usually contains salt but a limited quantity is made without it. Dairy butter is made on the farm as a domestic product while creamery butter is factory manufactured.

The process of butter making does not destroy pathogenic bacteria which may be in the cream or enter the product through improper handling. Therefore all sanitary safeguards comparable to those of fluid milk must be utilized.

Cream is usually separated from the milk on the farm, held for a short period in cooled storage below 60° F. and then transferred to the creamery. Both sweet and sour cream are pasteurized at the creamery. Pasteurizing should be accomplished by heating the cream to 155–160° F. and holding it at that temperature for 30 minutes, or by heating momentarily to 190–200° F. Prompt cooling should follow either method. After pasteurization

the cream is "ripened" by addition of a lactic acid culture starter and held in vats at 60° F. for about 24 hours. After ripening the temperature is reduced to 50° F. for churning. This ripening is necessary to produce desirable flavors.

Churning is continued for about 40 minutes after which the butter milk is drawn off and the coagulated butter washed with pure water. Salt is then added and "worked" into the butter, which is then manually removed from the churn with a paddle and stored in wooden firkins (tubs) or packaged into cartons for consumer use. Final hardening takes place in a chill room at −10° F.

Strict sanitary procedures must be employed during the different operations. All equipment must be scrupulously clean, disinfected, and dried prior to use. The manufacturing processes must be conducted so that the butter is not touched by the hands or clothing of the workmen. Butter is a milk product and must be handled as such. It absorbs odors and so should not be stored with other materials having definite odors.

Butter is graded in accordance with standards set by the United States Department of Agriculture.[7] Flavor is the most important factor in establishing grade. The better grades are produced from sweet or only moderately sour cream. The following grades are those commonly encountered:

| | |
|---|---|
| U. S. Cooking grade | —a score of less than 89 |
| U. S. grade C | —a score of 89 |
| U. S. grade B | —a score of 90 |
| U. S. grade A | —a score of 92 |
| U. S. grade AA | —a score of 93 |

Oleomargarine is a butter substitute made by churning lactic acid cultured skim milk with vegetable oils. The milk is fortified with Vitamin A having about 9,000 units per pound of margarine. Manufacturing processes are similar to those for butter.

## Cheese

Cheese is a milk product made from casein or curd produced by bacterial activity called "ripening". There are many varieties of cheese on the market but the basic manufacturing principles apply to all types.

Cheese curing processes may destroy pathogenic bacteria but every sanitary precaution in the handling of the milk, cleanliness of equipment and handling of the fresh cheese should be observed. Pasteurization of the milk although desirable is not done routinely. Typhoid fever outbreaks have been reported from the consumption of "green" cheese.

Upon receipt at the factory milk is placed in vats of varying sizes, warmed to about 70° F., and inoculated with a "starter". This is a bacterial culture of lactic acid or sour milk, and rennet. After a firm curd has formed,

the whey is drained off and the curd is cut, "milled" into small particles, and salt is added to inhibit undesired fermentation. Varying amounts of curds are compacted into "hoops" by pressure. After formation of a solid mass the cheese is removed, bound with a cloth, and returned to the hoop where it is kept for about 48 hours. The cheese is then dried with a cloth and placed in a curing room at about 50° F., usually with controlled ventilation and humidity. Humidity should be kept between 40 and 70 per cent. Curing is sufficient after 14 days when the cheese is ready for use. If raw milk has been used a storage period of at least 6 months is desirable to eliminate any pathogenic organisms originally present in the milk.[17] Moldy cheese when present in the curing room, may be cleaned by brushing, washing, and drying. Cheese is packaged in wooden boxes or in small cartons for individual consumption. Storage should be at 34° F.

These general methods vary in many respects for different types of cheese. Cottage cheese is a good example. This cheese is not cured and has a high moisture content. Cream is added to give the desired texture. Only pasteurized milk and cream should be permitted in the preparation of cottage cheese. Storage of the finished product should be at about 40° F. to prevent decomposition.

Cheese factories must be kept very clean. All equipment must be cleaned after use, and sterilized. Curing rooms may become infected with the cheese fly, and require appropriate insect control measures. Sanitary conditions comparable to those of the milk plant are required. Similar requirements apply also to personnel.

## SUMMARY

Milk is one of the most satisfactory and satisfying foods available to man. It can be used in its fluid natural state, as a confection in ice cream, or as a solid food in cheese. It is a food that is peculiarly susceptible in many stages of handling to contamination that may render the final product harmful. Every step in the handling and processing of milk and milk products must be watched carefully so that there will be no contamination. This watching is a responsibility of the whole health department team. Education and patience will render most milk handlers valuable members of this team.

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[26] Frank, Leslie, C., Fuchs, Abraham W. and Dashiell, Walter N., Pub. Health Reports, **53:** 1386 (1938).

Chapter VI

# WATER SUPPLIES

Water is of peculiar importance to all public health people, since an adequate, hygienically safe supply is essential to the maintenance of human life. Our colonial history is tied intimately to available water supplies. The growth of modern industrial life is dependent on an adequate, satisfactory, and constant source of water.

In contradistinction to this essential role of water—of importance equally to the city planner, the industrialist, the public health nurse or physician—is the negative role of water in our life. Just as water opened new routes to commerce, so has it marked the means of transmission for several diseases that have been of paramount public health interest. The elimination of water-borne enteric diseases stands as a memorial to the combined work of the engineer, the bacteriologist, the epidemiologist, and the chemist. Maintenance of the present favorable occurrence of these diseases will be based upon a clear understanding by all public health personnel of the need for a safe water supply.

The most important water-borne diseases are dysentery, cholera, typhoid fever, and amebiasis. Feces and urine, discharged by persons suffering from these diseases, or by carriers, always are the source of contamination. The causative organisms of these diseases do not reproduce in water but die rapidly after a few days. Under normal conditions they may live for a maximum of 28 days, although many die before this. The actual number of disease organisms in a polluted water supply is usually small and the water is only a temporary habitat, serving as a medium of transfer from the infected person to others in the community.

*Eberthella typhosa* (B. typhosus) and *Spirillum cholerae* or "comma bacillus" are the pathogens responsible for the greatest number of water-borne disease epidemics. Cholera is found in Europe and Asia but has not occurred epidemically in the United States since 1873. Typhoid fever has been rampant at various times in many places and continues as an important water-borne disease.

The first recorded cholera epidemics to reach Europe or the United States began in 1817[17] in India and spread throughout Europe by 1830 reaching into northern Africa in 1832. Several other cholera pandemics occurred during the mid-nineteenth century. All followed the routes of trade or emigration. Infected drinking water and poor personal hygienic conditions were important factors in the spread of the disease.

An epidemic of cholera occurred in London in 1854, which was shown by Dr. John Snow to have been caused by polluted drinking water from a certain well located in Broad Street. The detailed epidemiology presented in the original report established beyond question that persons using other sources of drinking water were unaffected except as they may have become contact cases.[19] Conclusive evidence was developed which established the "Broad Street well epidemic" as the first proved infection of human beings from a water supply.

The disastrous cholera epidemic in 1892 in Hamburg, Germany, was caused by the pollution of the Elbe River with human wastes discharged from ships anchored in the stream. This epidemic proved the value of slow sand filtration to remove bacteria from water.[14] Both Hamburg and the adjacent city of Altona used the polluted Elbe River for water supply. The Altona supply was additionally contaminated by sewage from Hamburg, but was protected by treatment with slow sand filters. The epidemic was limited to the Hamburg area which used unfiltered water. This city, with a population of 640,000, had 17,000 cases and 8,605 deaths, while Altona, with 14,300 inhabitants, had only 500 cases with 39 deaths. It was easily demonstrated that the Altona infections were contact cases or resulted from use of the unfiltered Hamburg water supply.[9]

The first epidemic of typhoid fever traced to a water supply occurred in Lausen, Switzerland in 1872. In a population of 780 some 130 cases appeared between August and October. Investigation proved that the infection came from the public water supply which was obtained from a spring or "well" fed by a subterranean stream. Actually the source of the spring was a brook located on the opposite side of the mountain from Lausen. Wastes from a typhoid patient were thrown into the brook some 2 miles distant from the spring, contaminating the town supply.[18]

Many investigators in recent years have questioned the relationship of water to the spread of poliomyelitis. The virus of poliomyelitis has frequently been recovered from sewage, however, water is *not* a vector for this disease. Chlorination of water supplies will inactivate the virus.

Rigid control of water supplies has been the most important factor in the decrease of the typhoid fever death rate since the beginning of the Twentieth Century (Figure 24). Despite modern purification processes epidemics of water-borne typhoid fever, diarrheas and dysentery have occurred at frequent intervals during the past 25 years. As shown by Table 4 these epidemics may be traced to various sources. The most serious in number of persons affected were caused by the use of untreated lake water, surface pollution of wells, overflow from a sewer line into the top of a well, inadequate control of purification, inadequate chlorination, cross connections to polluted supplies and seepage of sewage into the water distribution

lines.[1, 5, 8, 22, 23] The smaller cities and towns have suffered the most. Table 5 discloses that 65.70 percent of the epidemics occurred in cities with less than 5,000 population and only 1.58 percent in cities over 1,000,000 persons.

Courts have generally awarded damages against both private and public water supply officials found responsible for water-borne illness. This has become an established principle, particularly when negligence or incompetence is proved. The city of Olean, New York, as an example, was forced to float a special bond issue of $350,000 to cover damage verdicts obtained by victims of a water-borne typhoid fever epidemic in 1929.

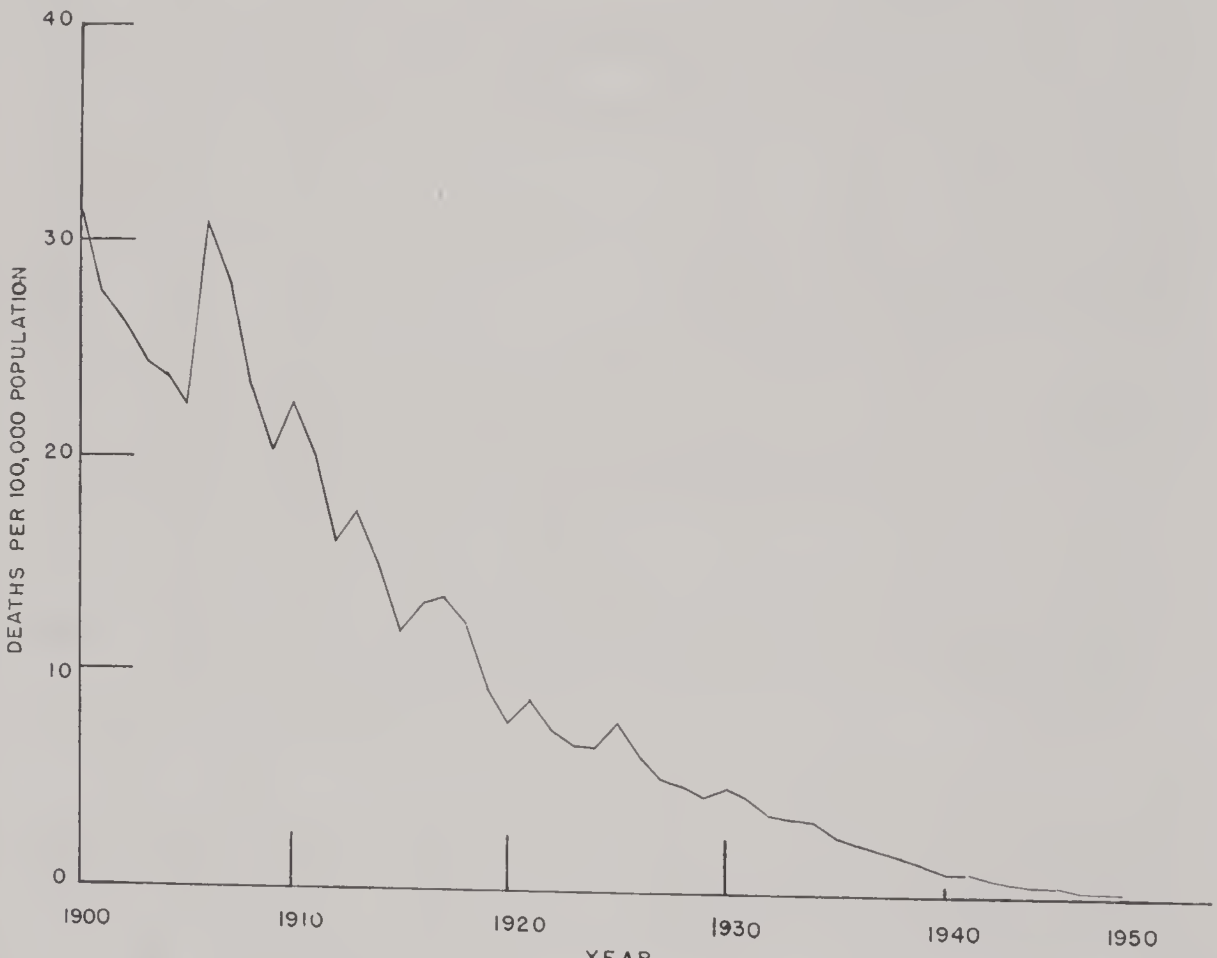


FIG. 24. Typhoid death rate curve, registration area of the United States

Health and water supply officials must recognize that many outbreaks could have been prevented by strict supervision of plant operation and elimination of potential pollutional hazards. This is illustrated by Table 6 showing the cause of the larger outbreaks in this country during the past 25 years. Human failure was a serious factor where purification facilities existed. Only constant, careful supervision by trained personnel and adequate facilities will give assurance that the water furnished to the public is always safe. Until these are furnished water-borne epidemics will occur.

TABLE 4

*Classification of Water-Borne Disease Outbreaks in the United States, 1920–1945**

| Classification | Outbreaks Reported | Cases of Typhoid and Paratyphoid | Cases of Dysentery and Diarrhea | Total Persons Affected |
|---|---|---|---|---|
| Surface water supplies: | | | | |
| Contamination of brook or stream from pollution on watershed | 38 | 694 | 3,143 | 3,837 |
| Use of polluted water from stream or irrigation ditch, untreated | 42 | 565 | 786 | 1,351 |
| Use of polluted lake water, untreated | 12 | 103 | 29,288 | 29,391 |
| Contamination of spring or infiltration gallery by pollution on watershed | 34 | 684 | 571 | 1,255 |
| Contamination of spring or infiltration gallery by flood waters | 10 | 185 | 400 | 585 |
| Underground water supplies: | | | | |
| Surface pollution of shallow wells | 65 | 1,254 | 2,382 | 3,636 |
| Faulty well casing or construction | 20 | 209 | 621 | 830 |
| Pollution of well from adjacent river or lake | 9 | 35 | 447 | 482 |
| Pollution of well from adjacent sewer or sewage tank | 41 | 340 | 1,630 | 1,970 |
| Underground pollution of well or spring in creviced limestone or fissure rock | 32 | 881 | 1,984 | 2,865 |
| Underground pollution of well or spring, source unknown | 66 | 457 | 2,002 | 2,459 |
| Underground pollution of well by surface contamination | 25 | 176 | 1,076 | 1,252 |
| Overflow of sewer or flood water into top of well casing | 11 | 424 | 12,370 | 12,794 |
| Reservoir or cistern storage: | | | | |
| Seepage from sewer or surface into cracked cistern or reservoir | 9 | 585 | 1,419 | 2,004 |
| Reservoir polluted by flood waters | 2 | 4 | 46 | 50 |
| Water purification: | | | | |
| Inadequate control of filtration and allied treatment | 28 | 436 | 61,531 | 61,967 |
| Inadequate chlorination, only treatment | 44 | 1,523 | 9,910 | 11,433 |
| Interruption of chlorination, only treatment | 26 | 620 | 6,370 | 6,990 |
| Distribution system: | | | | |
| Pollution of water mains during construction or repair | 7 | 13 | 1,022 | 1,035 |
| Leaking water main and sewer in same trench | 2 | 47 | 40 | 87 |
| Cross connection or back-siphonage | 73 | 2,154 | 53,575 | 55,729 |
| Breaks in mains permitting sewage or polluted water to enter | 4 | 158 | 290 | 448 |
| Pump pit polluted by leaking sewer | 2 | 0 | 266 | 266 |

TABLE 4—Continued

| Classification | Outbreaks Reported | Cases of Typhoid and Paratyphoid | Cases of Dysentery and Diarrhea | Total Persons Affected |
|---|---|---|---|---|
| Collection or conduit system: | | | | |
| Auxiliary intake to polluted source | 6 | 74 | 2,300 | 2,374 |
| Seepage of surface water into tank or cistern | 14 | 1,814 | 9,553 | 11,367 |
| Miscellaneous: | | | | |
| Use of polluted supply because of objectionable taste or odor of public supply | 6 | 122 | 35 | 157 |
| Use of polluted water not intended for drinking | 16 | 201 | 1,037 | 1,238 |
| Cause of outbreak undetermined | 44 | 331 | 4,179 | 4,510 |
| Insufficient information for classification | 37 | 506 | 7,775 | 8,281 |
| Total | 725 | 14,595 | 216,048 | 230,643 |

* Basic information compiled from:

"The Significance of Water Borne Typhoid Fever Outbreaks", Wolman & Gorman, Williams & Wilkins Co., Balto., 1931.

Supplement, Amer. J. Pub. Health, **28:** No. 2, Feb. 1938.

Pub. Wks., **78:** No. 11, p. 24, (1947).

TABLE 5

*Outbreaks of Water-Borne Diseases in Relation to Population Groups, 1920–1945**

| Population | Number of Outbreaks | Percentage of Total |
|---|---|---|
| 1,000 and under | 221 | 31.70 |
| 1,000 to 5,000 | 237 | 34.00 |
| 5,000 to 10,000 | 95 | 13.63 |
| 10,000 to 25,000 | 56 | 8.04 |
| 25,000 to 50,000 | 29 | 4.16 |
| 50,000 to 100,000 | 15 | 2.15 |
| 100,000 to 500,000 | 27 | 3.88 |
| 500,000 to 1,000,000 | 6 | 0.86 |
| Over 1,000,000 | 11 | 1.58 |
| Total | 697 | 100.00 |

* Basic information compiled from:

"The Significance of Water Borne Typhoid Fever Outbreaks", Wolman & Gorman, Williams & Wilkins Co., Balto., 1931.

Supplement, Amer. J. Pub. Health, **28:** No. 2, Feb., 1938.

Pub. Wks., **78:** No. 11, p. 24 (1947).

## CLASSIFICATION OF NATURAL WATERS

The source of water is atmospheric precipitation, collectively known as rainfall, in the form of rain, snow, hail or sleet. The final distribution of

TABLE 6

*The Larger Water-borne Outbreaks in the Cities of the United States 1920–45**

| City | Period | Cases: Dysentery & Gastro-enteritis | Cases: Typhoid | Deaths | Cause |
|---|---|---|---|---|---|
| Salem, Ohio | Aug. 1920 | 7,000 | 884 | 27 | Pollution by sewage entering vitrified collection line. |
| Santa Ana, Calif. | Jan. 1924 | 10,000 | 369 | 28 | Contaminated well from sewer drain. |
| Winona Lake, Ind. | July 1925 | | 1,000 | | Cross connection with raw lake water. |
| Detroit, Mich. | Feb. 1926 | 45,143 | 8 | 1 | Inadequate purification. |
| Fort Wayne, Ind. | Mar. 1929 | 5,000 | 53 | 3 | Cross connection to polluted supply. |
| Charleston, W. Va. | Nov. 1930 | 6,500 | | | Pollution of river water by sewage and trade wastes during low water. Possibly caused by chemical irritation. |
| Chicago, Ill. | June 1933 | 1,409 | | 98 | Amoebic dysentery. Cross connection between sewer and hotel water supply system. Leaking sewer pipe polluted drinking water cooling tank. |
| Fitsburg, Mass. | Mar. 1934 | 2,500 | | | Watershed pollution. |
| Minneapolis, Minn. | May 1935 | | 213 | | Insufficient chlorine treatment during period of unusual raw water pollution. |
| Springfield, Mo. | July 1936 | 35,000 | 197 | 45 | Insufficient chlorine treatment. |
| Milwaukee, Wis. | Mar. 1936 | 120,000 | | | Undetermined |
| | Feb. 1938 | 29,500 | | | Insufficient chlorine treatment. |
| Rochester, N. Y. | Dec. 1940 | 35,000 | 6 | | Cross connection between polluted raw water fire supply and distribution system due to valve inadvertently left open. |
| Seymour, Ind. | 1940 | 2,250 | | | Improper operation of filtration plant as indicated by turbidity of effluent. |
| Gadsden, Ala. | 1941 | 10,000 | | | Faulty operation of filtration plant in absence of Superintendent. |
| Norton, Kan. | Sept. 1942 | 2,690 | | | Cross connection to sewer system through hydrant pits. |

TABLE 6—Continued

| City | Period | Cases | | Deaths | Cause |
|---|---|---|---|---|---|
| | | Dysentery & Gastroenteritis | Typhoid | | |
| St. Marys, O. | 1942 | 2,000 | | | Cross connection to polluted fire supply. Contamination caused by failure of check valves. |
| Harrodsburg, Ky. | 1943 | 1,166 | 106 | | Inadequate chlorination of auxiliary supply. |
| Bay City, Tex. | 1944 | 1,000 | | | Contamination of well by flood waters. |

* Basic information obtained from J. Amer. Water Wks. Asso., **31:** 225 (1939). Ibid., **40:** 509 (1948).

rainfall determines the quantity of surface or ground water found in any locality.

The average mean annual precipitation in the United States as shown by Weather Bureau records from 1876 to 1949 is 34.33 inches. It is of interest to note that the 1930–31 drought reduced the mean rainfall in the United States to a yearly average of 28.81 inches, the lowest on record. As illustrated in Table 7 it is apparent that rainfall rates vary from year to year in every community. Statistics of this nature are the basis for engineering calculations of available water sources.

For all practical purposes, the sources of water as used for human consumption or industrial needs, can be divided into two general types—surface supplies and ground water supplies. It is true that there are some special situations, in addition to these two categories, where rainfall is collected directly into reservoirs, as in the entire island of Bermuda where extensive areas of land are denuded and graded so that the rainfall striking the coral surface can be conducted into storage reservoirs. Many homes in the southwestern part of the United States also use the roofs of their buildings as catchment areas, draining the rainfall into cisterns where it can be stored for later use.

## Surface Water

Water found on the surface of the earth is known as surface water. Ponds, streams, and lakes are examples. The source of this water may be rain that falls directly into the stream or lake or flows into it from adjacent land surfaces. Springs or outcroppings of water from saturated earth strata may also serve as sources for bodies of surface water. As rainfall percolates into the earth, it creates an underground reservoir of water-saturated soil

TABLE 7

*Inches Annual Rainfall of the United States, 1876–1947*

| State | Maximum | Minimum | Mean |
|---|---|---|---|
| Alabama | 66.45 | 39.21 | 53.41 |
| Arizona | 27.83 | 7.83 | 13.85 |
| Arkansas | 62.17 | 35.27 | 48.45 |
| California | 42.13 | 10.35 | 25.98 |
| Colorado | 22.47 | 11.97 | 16.54 |
| Florida | 72.70 | 40.25 | 53.21 |
| Georgia | 63.14 | 36.84 | 50.09 |
| Idaho | 24.04 | 12.40 | 18.18 |
| Illinois | 49.39 | 26.25 | 36.79 |
| Indiana | 49.68 | 29.71 | 39.22 |
| Iowa | 44.16 | 19.89 | 31.79 |
| Kansas | 40.77 | 19.67 | 26.95 |
| Kentucky | 58.82 | 27.86 | 45.19 |
| Louisiana | 75.57 | 38.34 | 56.51 |
| Maryland and Delaware | 52.08 | 23.29 | 41.65 |
| Michigan | 34.97 | 22.62 | 30.50 |
| Minnesota | 32.67 | 14.77 | 25.44 |
| Mississippi | 71.03 | 38.31 | 53.26 |
| Missouri | 55.53 | 25.86 | 40.26 |
| Montana | 21.12 | 10.24 | 15.37 |
| Nebraska | 35.87 | 13.54 | 22.60 |
| Nevada | 14.06 | 4.87 | 8.99 |
| New Jersey | 63.33 | 35.28 | 45.58 |
| New Mexico | 28.24 | 9.46 | 14.49 |
| New York | 49.74 | 32.98 | 39.29 |
| North Carolina | 62.66 | 37.32 | 49.63 |
| North Dakota | 23.23 | 8.83 | 17.12 |
| Ohio | 50.37 | 26.61 | 37.93 |
| Oklahoma | 47.73 | 18.92 | 32.93 |
| Oregon | 34.70 | 19.22 | 26.31 |
| Pennsylvania | 52.67 | 28.82 | 42.08 |
| South Carolina | 64.19 | 60.80 | 63.00 |
| South Dakota | 25.35 | 14.28 | 19.10 |
| Tennessee | 59.78 | 36.74 | 49.66 |
| Texas | 45.64 | 16.21 | 31.07 |
| Utah | 19.31 | 8.38 | 13.41 |
| Virginia | 53.20 | 24.99 | 41.88 |
| Washington | 47.48 | 24.67 | 34.59 |
| West Virginia | 52.15 | 25.43 | 42.99 |
| Wisconsin | 41.64 | 22.45 | 30.62 |
| Wyoming | 19.42 | 9.81 | 14.25 |
| New England States | 53.49 | 33.11 | 41.85 |

which then serves as a water source for wells and springs. This underground water will also find its way into the rivers so that in general terms,

stream flow may be considered as being derived from surface runoff and also from ground water infiltration. Runoff flow is that portion of the rainfall which does not percolate into the ground and does not evaporate into the atmosphere. It comprises the major volume of stream flow and is in direct proportion to the amount and intensity of rainfall. It may be defined as the water discharged into a stream from a given land area. This area is known as the water shed. A one-inch depth of rainfall per acre would be equal to 27,154 gallons or 17.38 million gallons per square mile, if considered entirely as runoff water.

While there is a direct relation between rainfall and stream flow, estimates of the amount available in runoff could not be based upon that in any single year since there is considerable variation in rainfall both in the annual rate and between the months of any given year. Accurate information concerning the availability of a river for use as a water supply, can be obtained only on the basis of stream flow statistics recorded over a long period of time.

Storage reservoirs are frequently constructed to assure an adequate reserve supply. Their capacity, based upon an estimated water demand, depends upon the need for storing water during periods of excess rainfall so that the demand can be met at all times of the year. Since construction of new or additional storage facilities is costly and time consuming many cities are confronted with the hazard of inadequate storage volume usually attributable to the reluctance of communities to finance the required additions.

## Ground Water

Ground water may be defined as the subsurface water retained by the saturated soil. The upper limit of this zone of saturation is called the "water table".

Springs are created when the ground water flow reaches the surface through a rock fissure or an exposed stratum of porous earth. They range in size from about 200 gallons per day, as found on the average farm, to a daily flow of many million gallons. There are 65 springs in the United States that have an average yield of about 60 million gallons per day each capable of supplying a large city.[16] Silver Spring, Florida, is the most widely known example; it has a maximum discharge of 531 million gallons per day.

Spring fed streams are often the head waters of large rivers and ponds. Lakes created from these sources are common. Natural lakes may therefore be considered as an admixture of ground and surface waters.

A well may be defined as a shaft sunk into the ground to the desired water stratum. Shallow wells are usually less than 100 feet in depth and

penetrate the top levels of the earth. Deep drilled wells extend to great depths. Shallow wells are driven, bored, or dug. Bored or driven wells are only a few inches in diameter while dug wells are 3 to 6 feet across. Shallow wells are suitable for a private domestic supply. Public water systems generally utilize deep well sources having a more or less known and constant volume of flow.

## RURAL SUPPLIES

Private, domestic supplies are obtained, generally, from springs or wells. In certain areas of the country it is not uncommon to find people drawing water directly from lakes or streams. This is particularly true in isolated locations. The chances of obtaining a safe surface water supply are so remote that only spring and well supplies will be discussed. If surface supplies must be used, the water should be disinfected before use by heating, chlorination, or some equally effective method.

### Distances to Sources of Contamination

The Joint Committee on Rural Sanitation,[26] composed of representatives of various federal agencies and the Conference of State Sanitary Engineers, makes the following statement, in part, about the distances to sources of contamination that normally can be considered safe:

> "Because the determination of a safe distance between a groundwater source and a source of contamination is dependent on many factors it is impracticable to establish arbitrary distances which will be adequate under all conditions. Each installation should be inspected by a person with sufficient training and experience to evaluate all of the factors involved. . . . These distances were determined after due consideration of the available information and are as follows: pit privies, septic tanks, sewers, and subsurface pits, 50 feet; seepage pits, subsurface sewage disposal fields and barnyards, 100 feet; and cesspools, 150 feet. In addition to the above minimum distances, where the area adjacent to the water source is accessible to livestock, the site should be enclosed by a fence located, in all directions, not less than 100 feet from the water source. When drainage from barnyards or other areas used by livestock may reach the water source because of local topography or soil formation, a greater separation than 100 feet should be provided. All of the above are minimum distances and may be inadequate when all conditions are not favorable as in the case of creviced earth formations or very permeable soil. Requirements of the state health department concerned should be ascertained and observed."

### Springs

Essentially, a spring represents groundwater that finds its way to the surface of the ground either by subterranean pressure or by topographical

characteristics of the ground. If the water has originated as groundwater at some point distant from the site of the spring, a spring supply can be safe provided it is developed in such a way that surface pollution is kept out of it. Springs in lime-stone areas should never be considered safe. Likewise, in localities where shattered rock of any sort characterizes the subsurface geology, springs and wells should not be considered free from pollution. In either case, there is a strong possibility that the water will reach the spring or well without the protection afforded by the filtration of water through sand and the storage that results in the slow movement of the water through the soil.

Before any spring is considered as a source of drinking water, the ground in the vicinity should be examined to locate any possible source of pollution from an improperly placed septic tank absorption line, privy, or similar sources of human waste matter. Particular attention should be given to ground at an elevation higher than the spring, which might drain into it during rainfall.

If the survey of the adjacent area does not indicate any source of pollution, the spring can then be developed as a source of water. An impervious masonry structure should enclose it in such a way that surface water cannot enter. Obviously, the bottom of the structure should be left open for the admittance of the spring water. The ground around the spring should be graded so that surface drainage is away from the spring. If there is any possibility that unusually heavy runoff might enter the spring, diversion ditches should be dug in location that will lead the runoff away. The only reason for access to the spring is for occasional inspection; a door should be provided but it should be a tight fit and should be kept locked.

Water should be led from the spring through a pipe. It should never be dipped out. Gravity can be used to carry water to the house if the spring is located higher than the house. Otherwise, a power pump, either electric or gasoline, must be used. Figure 25.

There are several danger signs that indicate an unsafe supply in either a spring or well. If color or turbidity is noticeable shortly after a rainstorm it indicates that water is gaining access to the spring in a short time, possibly through a fissure in the surrounding rock or through drainage around the spring house. If the water level in the spring fluctuates frequently to any great extent this is a further indication that the water is probably of local origin and more likely to carry pollution than would be the case if it passed through great distances in the earth.

## Wells

Wells are generally divided into three distinct groups: dug, driven, and drilled. The dug wells are excavated holes, 3 to 6 or more feet in diameter, lined with some solid material to prevent the walls from caving in. They

may be only a few feet deep or they may extend down 30 or 40 feet. Driven wells are formed by driving to the desired depth a pipe equipped with a driving point for piercing the earth and a metal screen to admit water to

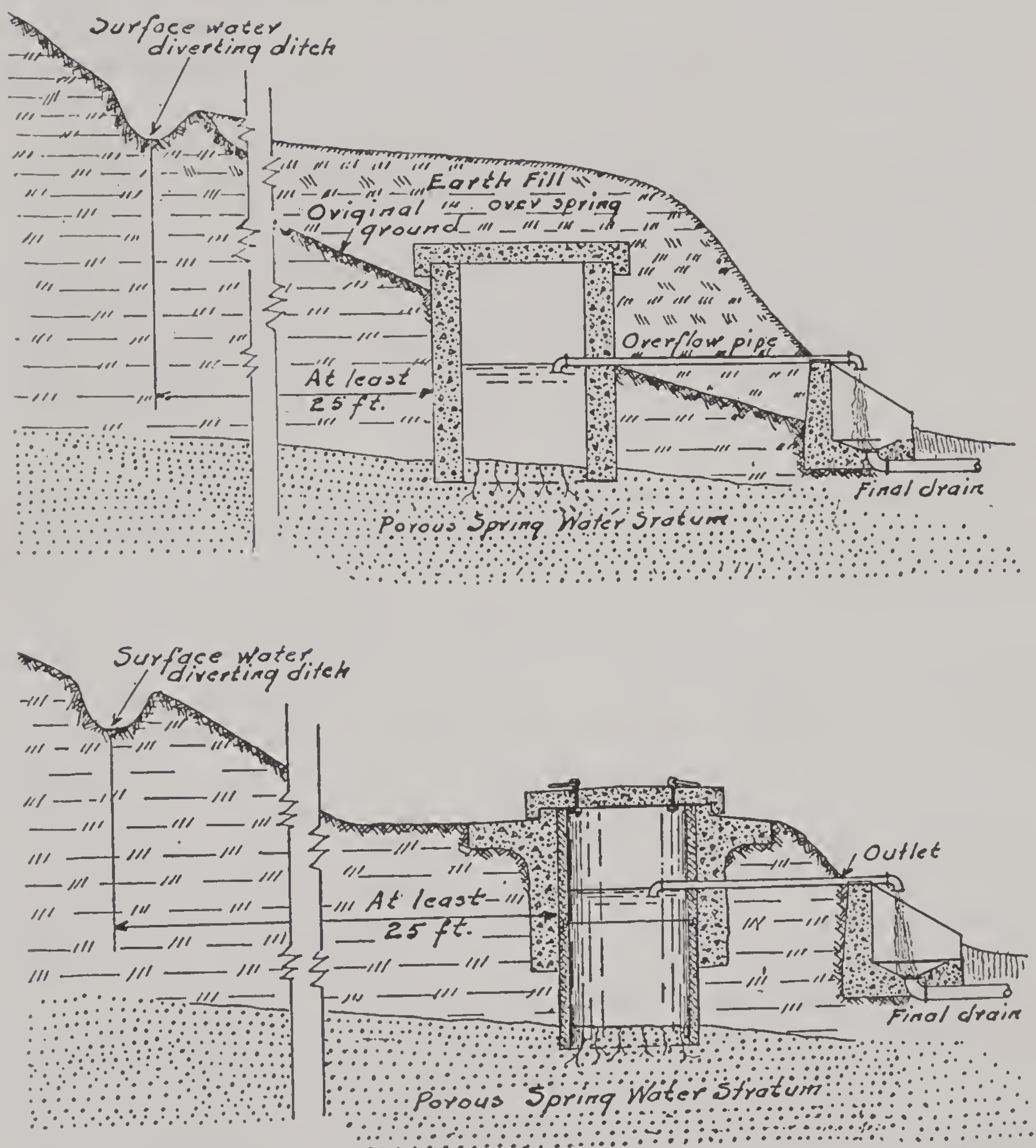



FIG. 25. Suggested method for protecting a spring. (Courtesy, Richard Messer, Virginia Department of Health.)

the pipe. These wells are used where groundwater is 25 or more feet below the surface of the ground. Although the usual diameter of a driven well is $1\frac{1}{2}$ to 3 inches, larger wells can be driven. These wells are feasible only where the ground is free of large rocks or boulders. The drilled well is formed by actually drilling through subsurface strata of rock and driving through gravel and sand strata until a suitable supply of water is found.

Such wells may be several hundred feet deep and are usually about 4 inches in diameter. The drilled well is the safest type; the driven next in order of safety.

### *Dug Wells*

Dug wells require a minimum of equipment to construct or operate. In rural areas of poor economic conditions, they are found frequently. The safety of any well water supply is dependent upon the prevention of pollution from entering the well. The water in the well may be polluted either by material washed in from the surface of the ground or else by

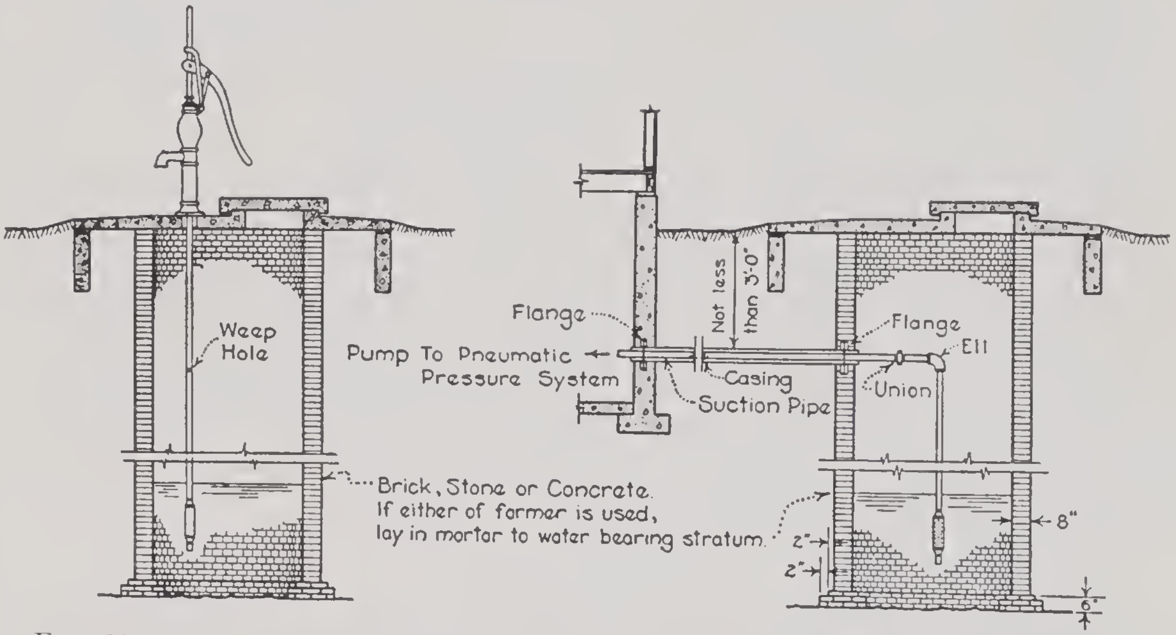



FIG. 26. A typical dug well. (Courtesy, George L. Hall, Maryland Department of Health.)

filtration through depths of earth too shallow to permit removal of harmful organisms. It is evident that a dug well should be located in such a place that it will not be subject to flooding or to pollution from sewer lines or other sub-surface sources of contamination.

Ideally the lining should be impervious, either stone laid in mortar, or else sections of tile or cement pipe; it should extend from the water bearing stratum up to and at least 6 inches above the surface of the earth. If these ideal conditions cannot be obtained, the least that should be considered is an impervious lining that extends from at least 10 feet below the surface to 6 inches above the surface of the ground. The top of the well should be impervious, preferably concrete, and should be large enough to extend several inches beyond the well proper. The top of the well and the ground around it should be graded so that any water falling on or in the vicinity will be drained away.

Some means of pumping water out must be provided. A drop or any other kind of bucket should not be used. The drop pipe through which the water is pumped from the well should be sealed into and carried up above the cover of the well so that the pump can be connected in such a manner that there will be no danger of water draining down into the well around the pump connection. Inspection should be provided for through a properly constructed manhole. The rim of the manhole should extend above the top of the well cover and the manhole cover should extend beyond the rim and be provided with a lip that overlaps it.

The pitcher type of pump should not be used, and any other type that needs priming is equally hazardous and should be eliminated. The act of priming can readily be the means of introducing pollution into the well.

Likewise, pump pits that are constructed within the walls of the well should not be encouraged. There is always a certain amount of oil, dirt and waste water in such pits. It is much better to house power pumps above the surface of the ground. If it is necessary to construct a well pit in the well proper, the pit should be made water-tight except for a drain to conduct leakage, oil, etc., out of the pit to a location that will not endanger the well supply. Electric, all weather, pumps that do not require a well pit are now available, thus eliminating one of the principal reasons for the well pit. The weep hole of the drop pipe, through which water drains to empty the pump, should be located below the impervious cover and in such a position that water will drain back directly into the well.

### *Driven Wells*

The construction of these wells requires equipment that usually makes it necessary to employ the services of a contractor. The best guarantee of a safe well is a contractor who is well trained and who has shown by his record that his work is good.

The physical requirements of the site for a driven well are the same as those for a dug well. A metal casing, known as a drive pipe, serves as the conduit through which water is drawn from the subsurface water-bearing strata to the pump. Before the driving starts a well point is attached to the end of the pipe that is to enter the ground. This well point consists of a pointed, heavy end that pierces the ground. Above it is a section of perforated non-corrodible tubing known as the strainer. Water passes through the strainer into the drop pipe.

As with the dug wells, the cover of the well should be of an impervious material such as concrete. The drop pipe usually passes through a sleeve in the cover so that the pump, if of the hand type, can be attached. The sleeve should be cemented into the cover and extend at least 2 inches above

it. If a hand pump is used, it should be secured firmly to the cover and connected to the sleeve so that water cannot splash back into the well.

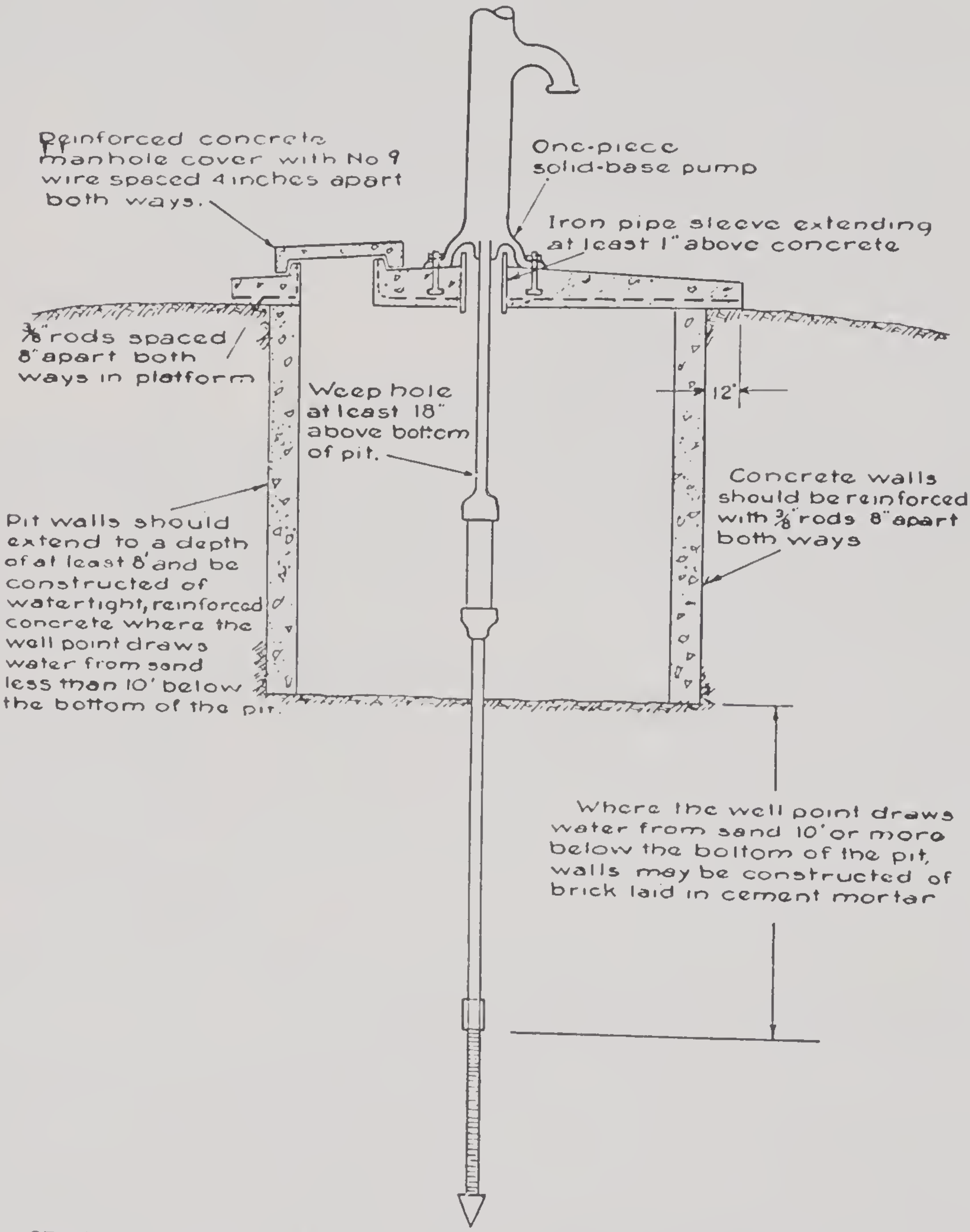



Fig. 27. A typical driven well. (Courtesy, Clarence W. Klassen, Illinois Department of Public Health.)

The cover, pump and casing must provide an absolutely water-tight superstructure to the well.

Some driven wells use a drop pipe large enough to permit the location of a submerged well pump in the pipe. When such is done it is still necessary to assure tight connections to the water distribution system.

### *Drilled Wells*

Drilled wells are the most satisfactory type of domestic water supply where it is not possible to connect to a municipal supply. The depth to which drilled wells extend usually assures a good degree of security against pollution. Most drilled wells pass through an impervious layer, such as rock or heavy clay, which presents another barrier to any surface water that might reach the casing. In general, these supplies are more dependable as to quantity of water and are less affected by long droughts.

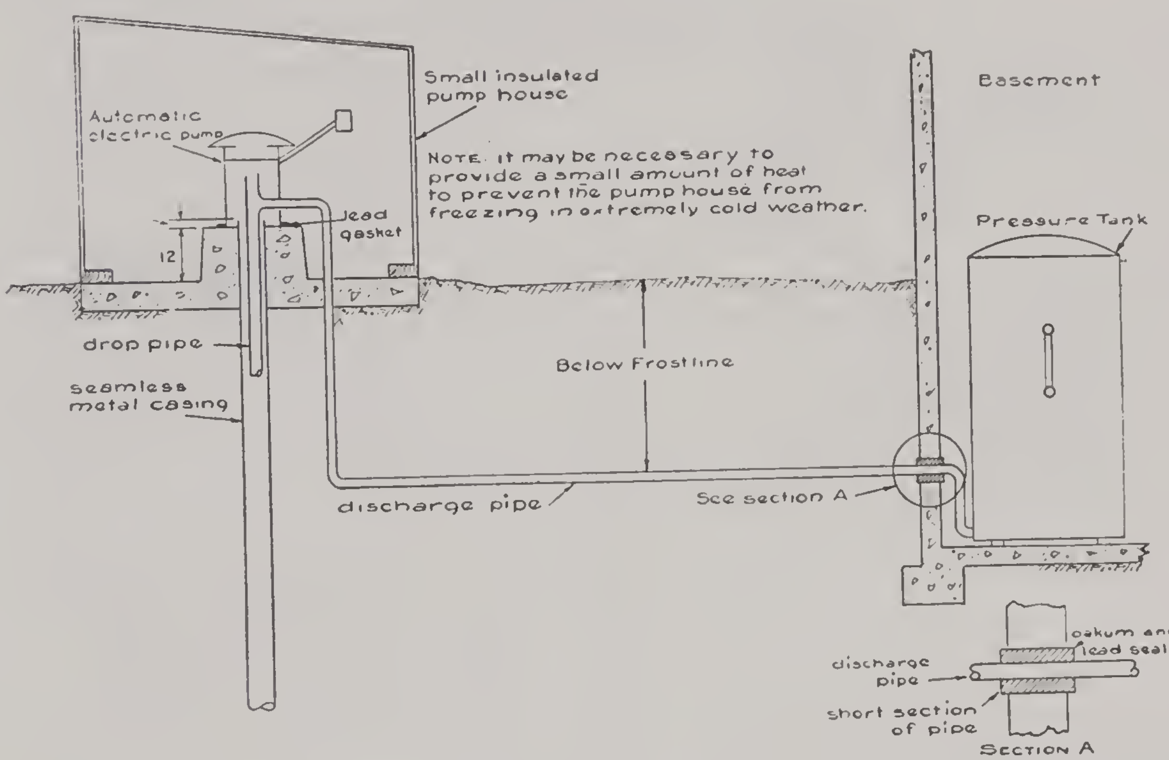



Fig. 28. A typical domestic drilled well and pressure system. (Courtesy, Clarence W. Klassen, Illinois Department of Public Health.)

A special well-drilling rig and experience are necessary for the construction of these wells. Here, as with the driven well, employment of a good well-driller is the best guarantee of a safe supply. The casing that forms the outer lining of the well is usually driven down until it reaches an impervious stratum. From there on the well is usually drilled until the desired depth, and water-bearing capacity, is reached. Good construction includes sealing of the casing into the rock or clay stratum so that a water-tight channel extends from the top of the well down through the impervious layer. The riser pipe or pipe through which the water will actually be conveyed, is then extended down to the desired depth.

A water-tight connection at the surface of the ground is necessary. Submerged well pumps are usually used in the drilled well unless a water-bearing stratum under pressure is struck, so that the water is driven by

hydrostatic pressure above the surface of the ground or at least part way up to the surface. (This is the true artesian well.) A storage tank, with the water maintained under pressure, is generally part of the distribution system. The entire distribution system, from the well, to the storage tank and to the house, barn, or other buildings, should be water tight.

## Disinfection of Wells and Springs

The water supply to a private home is seldom chlorinated, although there are convenient chlorinators for this. However, the well should be carefully disinfected upon completion of construction and before the water is used for drinking purposes.

### *Dug Wells and Springs*

As soon as construction has been completed, remove all tools, forms, platforms and anything that will not form a permanent part of the well. Wash the interior walls or casing with a strong solution of chlorine, at least 100 ppm, using a stiff brush to scour out loose dirt. Pump the water from the well until it is clear and then remove the temporary pumping equipment used for this purpose.

The next step consists of placing the cover in its final position and sealing it in place if that is to be done. Next, having determined the amount of water that will accumulate in the well, pour into it through the sleeve in the cover sufficient chlorine to give a residual of approximately 50 ppm. The chlorine must be distributed throughout the water in the well. This can be done by pumping the solution through a rubber tubing or pipe line that can be moved about in the water in the well while the solution is being added to the water. When the required amount of solution has been added, the pump cylinder and drop pipe, previously cleaned, are lowered into the well, attached to the sleeve in the cover, and bolted to the cover. Sufficient water is then pumped through the system to flush out all unchlorinated water in the riser pipe and pump, or until a strong odor of chlorine is detected in the water discharged from the pump.

The chlorine solution should be allowed to remain in the well and equipment for at least 24 hours. The water should then be pumped out vigorously until there is no odor of chlorine. It is important to provide a conduit through which the discharged water can be conducted away from the well in order to minimize the possibility of any of the water running back into it. Upon completion of pumping the well is ready to be used. If time is not important, a sample of the water should be withdrawn and submitted for laboratory examination. If results are not satisfactory, the well site should be re-examined for possible sources of pollution. If none is found the chlorination procedure should be repeated after first removing the pump.

### *Drilled Wells*

In these wells there is no way to observe the quantity of water that flows into the lower portions of the well and so the capacity is determined by actually measuring the pump output. If the process of measuring flow does not produce a clear water, pumping should be continued until all traces of turbidity disappear. When the test pump is removed the chlorine solution, sufficient to give a residual of about 50 ppm, should be poured into the casing. Thorough distribution of the solution is important. It is good practice to introduce the solution through a rubber tube or a pipe so that the hose or pipe can be slowly raised and lowered as the chlorine is poured into the water in the well.

The pump cylinder and drop pipe, previously cleaned and rinsed in chlorine solution, are then lowered into the well and the top connections made. Water should be discharged until a strong odor of chlorine is noticed. This should be repeated several times at hourly intervals to be sure the chlorine solution has reached all parts of the system. The solution should then be allowed to stand for at least 24 hours after which the well should be pumped until the odor of chlorine disappears from the water. As with the dug well, a sample of water can then be taken for bacteriological examination.

*Liquid Capacity of Wells or Spring Structures and the Amount of Chlorinated Lime (25% available chlorine) Required to Provide a Dosage of Approximately 50 ppm of Available Chlorine*

| Capacity of well or spring (*in gallons*) | Chlorinated lime required* *Lbs.* | *Oz.* | Approximate volume of water, in gallons, to be used in preparing chlorine solution |
|---|---|---|---|
| 50 | — | 1.5 | 5 |
| 100 | — | 3.0 | 5 |
| 200 | — | 6.0 | 5 |
| 300 | — | 9.0 | 5 |
| 400 | — | 12.0 | 5 |
| 500 | — | 15.0 | 5 |
| 1000 | 1 | 14.0 | 10 |
| 2000 | 3 | 12.0 | 15 |
| 3000 | 5 | 10.0 | 20 |

* If high-test calcium hypochlorite, approximately 70% available chlorine, use about one-third of the quantity shown for chlorinated lime.

## Laboratory Analyses

All too often samples of water are sent to the laboratory for examination without any consideration being given to the physical characteristics of the well. It is important to bear in mind the fact that a laboratory report can only tell the quality of the water at the time the sample was taken or

verify the results of a physical examination. A laboratory test may produce a false sense of security. On the other hand a bad laboratory test may lead to the abandonment of a well that could be made safe with a minimum of work. The most important aspect in determining the safety of a well supply is the investigation of the physical features of the well—geology, nearby sources of pollution, construction of the well, type and installation of the pump, grading around the well. Unless all of these characteristics are satisfactory, laboratory samples are of little use. Once these physical characteristics have been found acceptable, then laboratory tests can be used routinely to check the continuing quality of the water.

## WATER CONSUMPTION

The quantity of water required per capita in the various cities and towns varies enormously. This is due to diverse industrial activities and, to a

TABLE 8

*Domestic Consumption of Water**

| | Gallons per capita per day |
|---|---|
| Apartment House | 62 |
| First Class Dwelling | 54 |
| Middle Class Dwelling | 34 |
| Lowest Class Dwelling | 15 |
| Average | 41 |

* Data taken from "Water Supply and Purification", W. A. Hardenbergh. International Textbook Co., Scranton, Pa., 1947.

lesser extent, the water consuming habits of domestic users. In the larger cities of the United States consumption ranges from 90 to 300 gallons per capita per day while in the smaller communities, with less industrial demand, it is between 40 and 140 gallons. The average for all cities in this country in 1945 was 127 gallons per capita.[27, 28]

Domestic consumption averages about 50 gallons per capita per day. This is illustrated in Table 8. Fire protection requirements exceed domestic demand and usually determine the capacity of the distribution system in residential areas.

In rural areas, allowances must be made for animals and fowl. Such farm life requirements are:

35 gallons per cow per day
12 gallons per horse per day
4 gallons per hog per day
2 gallons per sheep per day
1 gallon per 25 chickens per day

## PUBLIC WATER SUPPLIES

Many storage reservoirs were built in ancient times. Lake Maeris in Egypt, retaining waters of the Nile river, is thought to have been built about 2,000 B. C. The early civilizations of Babylon and Assyria were largely dependent upon irrigation systems using stored flood waters of the Tigris and Euphrates rivers. The ancient cities also obtained water by storing rainfall in pools or cisterns or by bringing it long distances through conduits. Mention is made in II Kings, 20th Chapter, of the pool and conduit King Hezekiah built in the 8th Century B. C. for Jerusalem. Some of these old well developments are used today. Joseph's well at Cairo, Egypt, and Jacob's well at Sychar, Palestine, are the best known.

The water supply of Rome was extensive and complete. The initial aqueduct was built in 312 B. C. and was 11 Roman miles long. By 300 A. D. there were 9 aqueducts delivering 77 million gallons per day. The clear sparkling water of the Marcia aqueduct was especially used for drinking.

Upon entering the city the water was discharged into large cisterns and distributed through lead or wooden pipes to smaller tanks for use. The small public cisterns were the principal sources of drinking water. The famed baths were directly supplied from the central reservoirs. By 337 A. D. there were 11 large hot water baths, 925 cold water baths, 1212 public fountains and 247 reservoirs in the city.[11] After the fall of Rome these elaborate water carriage systems were abandoned and later fell to pieces, as was also true of similar systems in the provinces.

In 1183 an aqueduct with a flow amounting to about 1 quart per person per day was constructed to supply water to Paris. Conduits and lead pipe systems were built in 1235 to bring spring water to the people of London. The first pumps for water supply were installed in Hanover, Germany in 1527. In 1582 pumps were placed on the Tower Bridge over the Thames to supply water to London. The first steam driven pumps were installed in London in 1761. This date may be considered as the beginning of modern water works. The first water works pumping station in the United States began operation in May 1755 at Bethlehem, Pa., using a water wheel for power.

In 1804 the entire water supply of Paisley, Scotland was filtered. The Chelsea Water Company, under the direction of James Simpson, installed the first sand filter in London to *clarify* the Thames river water in 1829. It was about 1 acre in area. This installation was so successful that by July 1852 filtration of all river water supplied to London was made compulsory by Parliament.

The development of sand filtration had progressed to the extent that by 1865 many European cities were using this system of clarification. Recog-

nizing the value of these slow sand filters, the Water Commission of St. Louis, Mo., in 1865 sent James P. Kirkwood to Europe to study their operation. His report, published in 1869, was descriptive of these plants and endorsed their efficiency for the purification of comparatively clear waters but proved them uneconomical for muddy water without prior sedimentation.[13] In 1872 Kirkwood built the first successful slow sand filter plant in this country at Poughkeepsie, N. Y.

The Massachusetts State Board of Health established the Lawrence Experimental Station in 1887 to study and devise methods for the purification of sewage and industrial wastes.[21] Considerable study was also undertaken with slow sand filters for water purification. As a result of these studies, Lawrence, Mass., constructed a slow sand filter plant in 1889; it is considered to have been "the first filter plant built in America for the express purpose of reducing the death rate of the population and it accomplished this purpose in a most striking manner."[10] This demonstration of the practical epidemiological value of these filters led to their adoption by New England and Atlantic seaboard cities.

Chemical coagulation with alum followed by filtration through sand filters with backwashing of these units under water pressure and using mechanical rakes to agitate the sand was patented in 1884. This process became known as mechanical filtration. The first mechanical plant for a public water supply, constructed under this patent, was built at Somerville, N. J., in 1885.

The underlying facts governing rapid sand filtration were developed by experiments undertaken at Louisville, Ky., from 1895 to 1897, utilizing the turbid Ohio River water. Under the direction of George W. Fuller, this investigation demonstrated that mechanical filtration could be operated efficiently and adapted to muddy waters. In this treatment alum was added to the water as a sedimentation aid. The alum solution formed a particular floc or precipitate that sank through the water carrying much of the colloidal and suspended matter with it.

The detailed data published in 1898 revealed that satisfactory clarification and purification were obtained with the use of alum as the coagulant, although mixing velocities and types of mixing basins were not investigated.[6] This study included the backwashing of filters by the rapid upward flow of water under pressure and established the value of a controlled rate of filtration. Using sand of 0.46 mm. diameter for the top size and beds 30 inches in depth, with application of coagulated and settled water, good purification was secured at filtration rates of 1.6 gallons per square foot per minute or 100 million gallons per acre per day. This rate was approximately fifty times greater than that of the slow sand filter.

Water purification as now practiced rests upon the facts obtained and

procedures established in the Louisville experiments. From that modest beginning and in the period of but 50 years this type of purification has become world wide. The magnitude of the growth of water purification plants is illustrated in Table 9 compiled from a recent survey by the United States Public Health Service.[20] It will be noted that about 38.0 percent of the population of this country is supplied with treated water.

The modern filtration plant produces a water that is free from pathogenic bacteria, turbidity, odor or color. In many instances the water treatment removes hardness and retards corrosion of pipe lines.

TABLE 9

*Water Treatment Plants in the United States*

| Classification | Number of Plants | Population Served | Per Cent of the Total Population of the United States* |
|---|---|---|---|
| Rapid sand purification | 1535 | 22,921,600 | 17.4 |
| Slow sand purification | 98 | 3,579,200 | 2.7 |
| Iron and manganese removal | 456 | 1,892,000 | 1.4 |
| Softening | 396 | 1,725,400 | 1.3 |
| Chlorination only | 2529 | 19,432,700 | 14.8 |
| Treatment without chlorination | 138 | 511,000 | 0.4 |
| Total treated supplies | 3152 | 50,061,900 | 38.0 |

* S. R. Weibel, Public Health Reports, **57:** 1679 (1942).

## *Selection of Water Supplies*

After the estimated future water requirement of a community has been determined it becomes necessary to locate an adequate source of supply. Quantity is the most important factor in the selection of a source. The capacity of the plant is designed for requirements as estimated for 25 to 50 years in the future, the specific interval depending upon feasible financing programs.

In the selection of a public water supply, the engineers planning the development, after a study of rainfall data, stream flow, and other physical factors, frequently must choose between utilization of a source of adequate sanitary purity and one having a large volume of available water. This is illustrated in the selection of a river rather than a series of wells. It is proper to consider the purity of the source as of secondary importance since modern purification procedures can render most waters safe for use. Although generally established upon this basis, instances appear where cities possessing the advantage of unlimited surface supplies have persisted in the development of existing ground water sources. This is pri-

marily due to the fact that public sentiment has become fixed upon the existing source and refuses to permit a change. Thus sentiment and custom may have a bearing upon the future development of water supplies, sometimes to the detriment of the community.

Bacterial contamination of water sources results from the direct addition of sewage or sewage plant effluent, defective sewer drains, and overflowing privies and cesspools. Street washings resulting from storms add to the bacterial load. Industrial wastes, although they too may add bacterial contamination, are usually more important because of the obnoxious odors and colors imparted to the water and to the adverse effect they may have on normal water purification procedures.

An epidemic resulting from the pollution of a water supply with cholera, dysentery, or typhoid fever bacteria is the hazard to be considered. The general sanitary characteristics of the water shed, whether it be a surface or ground water source, must be evaluated. The possibility of human pollution reaching the community will determine the need for a complete purification plant. Individual phases of purification, such as storage in large reservoirs followed by chlorination, are considered adequate in some localities. Limited treatment of this sort may be adequate if the quality of the water, initially, is good and chance of pollution slight. Whenever there is any question of safety, complete purification is necessary. Such treatment is particularly desirable if tastes, odors, or colors are present.

## Use of Ground Water

It is estimated that 19 percent of the population and 46 percent of the cities in the United States are dependent upon ground water sources. Cities with populations below 25,000 generally use well waters.

Ground waters are usually cool, colorless, and free from turbidity except when iron or manganese salts are present. They are constant in composition and are often hard, containing excessive amounts of calcium and magnesium. Hydrogen sulfide may be present and carbon dioxide is commonly found. Hydrogen sulfide is usually the result of anaerobic bacterial action. Acid constituents, sulfates, chlorides, and nitrates are dissolved in the water from the earth.

By reacting with the calcium and magnesium carbonates in the soil, the dissolved carbon dioxide is responsible for the hardness of a water. It also dissolves and retains in solution iron and manganese salts. As would be expected, the average hardness of ground water is greater than that of surface waters, namely 191 ppm. compared to 85 ppm.

For a public supply, one or more wells are located in an area that has been selected after consideration has been given to local conditions and data

obtained from comparable rock and soil characteristics. The wells are spaced from 400 to 1,000 feet apart and vary from 8 to 24 inches in diameter.

Deep drilled wells are commonly used. They are normally cased with iron or steel pipe from the ground surface to the water level. The space between the casing and the drill hole down to an impervious stratum is filled with concrete grout to form a tight seal between the casing and the surrounding earth thus preventing surface water from entering the ground water stratum. Water is admitted to the well through a brass strainer at the bottom of the pipe.

Electrically operated, centrifugal, turbine pumps are usually used to raise the water. Pump houses containing the pumps are frequently built, similar in construction to those for domestic supplies with concrete floors and substructure and a brick super-structure. They serve also to house chlorination units, electric transformers and meters for recording flow. Several wells may be discharged into a common header or collecting pipe. Chlorination is commonly applied and water flow data is secured at the header.

Well water supplies are relatively safer from pollution than springs or surface streams. This depends to a very large degree upon their location and construction. Sanitation of ground water public supplies has been given considerable study and a manual has been compiled showing development characteristics.[24] Pollution of a deep well will occur through seepage of surface water into the top, leakage through the sides of the casing, or from contamination of the underground stream. The latter hazard is particularly great in limestone areas where underground chambers or fissures may permit water to flow in free-moving streams without any appreciable filtering action.

As for domestic supplies, wells for public supplies should be constructed to afford protection from surface drainage and flood water runoff from storms. They should be located at a safe distance from sewage installations. Casings must extend above ground level with a watertight connection in the pump base and pass down through at least one impervious soil stratum, be tight at the joints, free from corrosion leakage, regularly inspected, and tested at frequent intervals. Suction lines should not be constructed in contaminated soil areas. Pumping equipment should be placed above any flood water level that might reach the pump house. There must be at least one reserve pump in case of breakdown, or to permit shutting down for routine overhaul.

Inadequate surface protection is the most dangerous hazard to a ground water supply. Spring or well waters becoming turbid after storms are generally fed from a rock fissure exposed to surface drainage and are

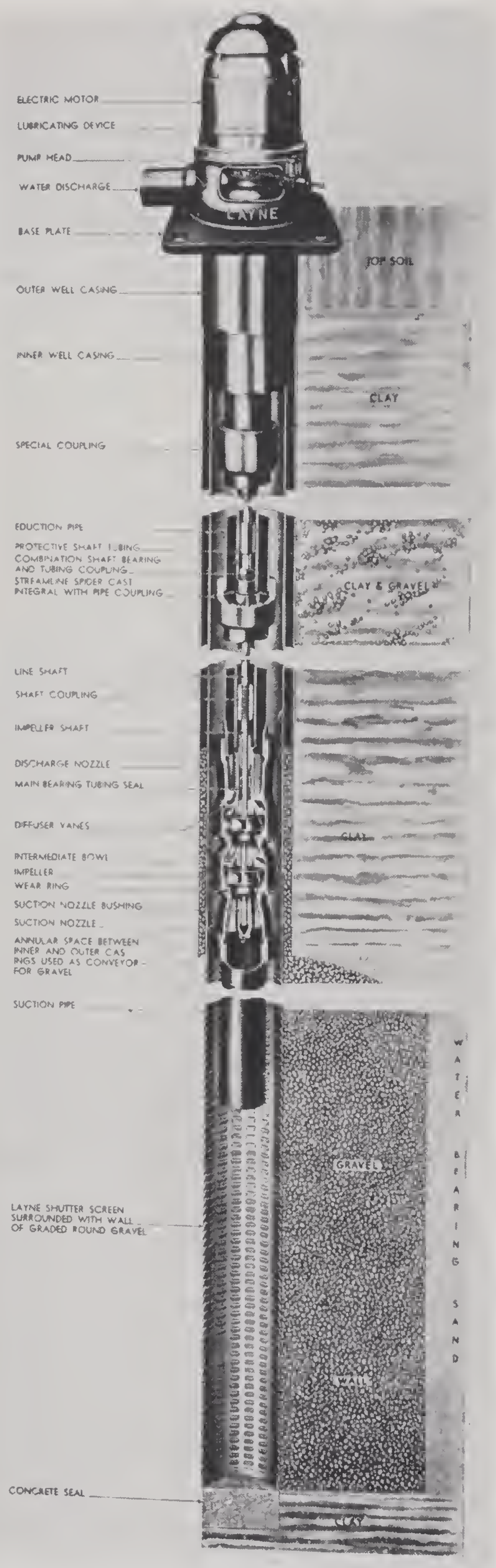



Fig. 29. A large drilled well for municipal supply. (Courtsey, Layne-Atlantic Co.)

unsafe. To assure the proper construction of wells, specifications have been devised by the sanitary engineering bureaus of the state departments of health, which if followed, will eliminate pollutional risks.

Ground water public supplies should be continuously disinfected although many cities fail to do so. The potential hazard of pollution is always present. Casing or pipe lines may leak in contaminated soils, while industrial or domestic pollution of the source is a constant menace. The average safety of a ground water supply does not justify its use without disinfection safeguards and in frequent instances complete purification may be necessary.

Iron and manganese removal, softening and corrective treatment for corrosion control are the principal purification operations for ground water supplies.

### Use of Surface Supplies

The average river or stream must be considered polluted. This is particularly true of the larger rivers. For example, the Ohio River receives sewage from Pittsburgh, Pa., at its source, and from bordering cities over its entire length to Cairo, Ill., where it joins the Mississippi River. The cities along the river purify this polluted water, use it for drinking purposes and in turn discharge their wastes into the stream thereby creating a greater hazard for the cities below. As a result of this practice, the Ohio River is in danger of becoming grossly contaminated to the point of being unsuitable as a source for public water supply.

Apart from these grossly polluted larger rivers, even small creeks and brooks generally free of pollution must be considered unsafe. Sanitary water boards in the various states have allocated streams for water supply, others for certain types of industrial waste disposal and in others permit heavy contamination. However, purification should be practiced for all surface waters. Clear water is not a criterion of safe water whether it be from underground or surface sources.

Surface waters, usually impounded by dams to form storage reservoirs, are used by the larger cities of the United States as the source of water supply. The quantity required by most cities can only be assured by utilization of suitable reservoirs or by the flow from reasonably large rivers or lakes as illustrated in Table 10.

## RESERVOIR STORAGE

The formation of impounding reservoirs by damming surface streams and providing long storage periods is practiced in some localities as the primary method of purification. The coarser suspended material is precipitated, giving a fairly clear water. Oxidation of unstable organic matter

and a reduction in pathogenic bacteria occur. Chlorination of the water upon withdrawal is practiced as a safeguard against disease outbreaks.

TABLE 10

*Source of Water for the 25 Largest Cities in the United States (1940 Census)**

| City | Population | Source |
|---|---|---|
| New York, N. Y. | 7,454,995 | Catskill system, impounded surface water; Croton supply, impounded surface water; ground water, wells, 10%; Delaware River system, impounded, under construction. |
| Chicago, Ill. | 3,396,808 | Lake Michigan. |
| Philadelphia, Pa. | 1,931,334 | Delaware River 55%; Schuylkill River 45%. |
| Detroit, Mich. | 1,623,452 | Detroit River. |
| Los Angeles, Calif. | 1,504,277 | Owens River 80%; Los Angeles River 20%. |
| Cleveland, Ohio | 878,336 | Lake Erie. |
| Baltimore, Md. | 859,100 | Gunpowder River, impounded; Patapsco River, impounded, under construction |
| St. Louis, Mo. | 816,048 | Mississippi River 60%; Missouri River 40%. |
| Boston, Mass. | 770,816 | Nashua River, impounded; Ware and Swift Rivers, impounded as supplementary. |
| Pittsburgh, Pa. | 671,659 | Allegheny River. |
| Washington, D. C. | 663,091 | Potomac River. |
| San Francisco, Calif. | 634,536 | Tuolumne River, impounded and Spring Valley supply. |
| Milwaukee, Wis. | 587,472 | Lake Michigan. |
| Buffalo, N. Y. | 575,901 | Lake Erie. |
| New Orleans, La. | 494,537 | Mississippi River. |
| Minneapolis, Minn. | 492,370 | Mississippi River. |
| Cincinnati, Ohio | 455,610 | Ohio River. |
| Newark, N. J. | 429,750 | Pequannock River, impounded. |
| Kansas City, Mo. | 399,178 | Missouri River. |
| Indianapolis, Ind. | 386,972 | White River, impounded 80%; ground water, wells, 20% |
| Houston, Tex. | 384,514 | Ground water, wells. |
| Seattle, Wash. | 368,302 | Cedar River and Cedar Lakes. |
| Rochester, N. Y. | 324,975 | Hemlock and Canadice Lakes |
| Denver, Col. | 322,412 | South Platte River, impounded. |
| Louisville, Ky. | 319,077 | Ohio River. |

* 1950 Census not available.

The two most outstanding examples of this type of purification in the United States are at Boston, Mass., and New York, N. Y.

This procedure requires large reserve reservoir capacity. In the Catskill

system for New York, the Schoharie Reservoir has a capacity of 20 billion gallons, Ashokan Reservoir 130 billion and Kensico Reservoir 30 billion while the Croton system of twelve reservoirs and six lakes holds 103 billion gallons. In addition to these reserves three new reservoirs are under construction to divert water from the tributaries of the Delaware River. Boston has recently completed the Quabbin Reservoir which has a capacity of 415 billion gallons, extending its system by use of water from the Ware and Swift Rivers.

The responsibility for the sanitation of watersheds is vested in the various state departments of health. The use of impounding reservoirs and natural lakes for water supply creates sanitation problems on the watersheds. Under the doctrine of riparian rights, possession of the land adjacent to the reservoir gives absolute control over it, making possible enforcement of sanitary regulations by the water authority. Throughout the headwaters of the watershed, where private ownership of land usually exists, inspection of the area, in collaboration with the health authorities will do much to reduce pollution. The average inhabitant will provide sanitary privies and dispose of barnyard wastes satisfactorily when his confidence has been gained by an inspector. Resort to drastic legal action should be infrequent. Prompt examination of premises where typhoid fever has developed with instruction in the disposal of excreta and other wastes will greatly lessen dangers of epidemics from this source. Some water authorities have found it advantageous to install and service adequate waste disposal facilities for private land owners. An efficient watershed inspection service is one of the best sanitary safeguards for an impounded supply.

Reforestation of the areas adjacent to a reservoir will prevent erosion of the soil and materially reduce the turbidity of the water. The use of conifers is desirable as the leaves of deciduous trees blow into the water and decay, causing esthetic and bacterial impairment to the supply.

## Recreational Use of Reservoirs

The recreational use of reservoirs has become a controversial question in respect to the impairment of the sanitary quality of stored water. The most outstanding use of reservoirs for recreational purposes is at Springfield, Ill., where boating, fishing, camping and picnicking, with facilities provided by the water department, are permitted. An urban housing development has been erected on the lake shore with the inhabitants enjoying the usual bathing and other recreational activities on the watershed. A swimming pool of 240,000 square feet has been constructed in the lake for public use. The overflow of chlorinated water from this pool returns to the lake. Complete purification is given to the public water supply prior to use.[2]

In general, health and water department officials in the eastern part of the United States are opposed to extensive recreational use of reservoirs and the land adjacent to them. Similar officials in the western states where extensive use is encouraged, do not concur in this point of view.

Daily tests of water collected from several areas in a reservoir have failed to show that recreational use of reservoirs increased the bacterial concentration in the water. The total count and coliform density were not changed. It is apparent therefore that with very large reservoirs and with complete treatment of the water before use, a sanitary basis does not exist for the exclusion of controlled fishing or boating, or even picnicking and bathing.

Where recreational activities are permitted on a watershed, health authorities agree that their control should be under the direction of the water department and not delegated to another agency. The courts have recognized the necessity of protecting a watershed in the interest of public health even though such necessity restricts individual property rights. The laws of various states vary as to detail, but fundamentally hold that the owner of a water supply benefits from it and must protect the source. It is evident therefore that the water department should actively control its watershed.

Where filtration is not part of purification, and storage with resultant sedimentation, followed by chlorination, is the only safeguard, restrictions must be exercised. A water supply protected by an efficient filtration plant has adequate sanitary safeguards against the normal contamination that may occur, but treatment consisting of storage and chlorination does not have flexible safety factors.

It should be noted that there is a decided trend toward use of reservoirs and surrounding drainage areas for recreational purposes. This has been based largely upon the public relations value. It may be expedient, practical, and politic to permit fishing and boating under controlled conditions rather than to continue to prohibit such use when actual hazards cannot be shown to exist. This decision must be based on the circumstances of each case. If the reservoir is near a large center of population and there is no other large body of water nearby, there is a much stronger case for the recreational use than would be the case in a sparsely settled area with large lakes or streams not in the watersheds.

## Algae

Growths of algae, diatoms, crustacea and other micro-organisms will be found in all reservoirs at temperatures above 50° F. In water supply practice the term algae is often incorrectly used when plankton is meant; only plant life should be properly classified as algae, while plankton embraces both plant and animal forms. The blue-green algae (cyanophyceae)

are most prolific in warm weather and diminish in the colder seasons, but the diatoms live at low temperatures.

Concentrations of algae at reservoir surfaces utilize the dissolved carbon dioxide, changing the bicarbonate balance in the water and raising the pH value to 8.5 or 9.0. An increase in the dissolved oxygen will also be noted since this element is released by plant life.

All forms of plankton grow readily in water above 68° F., with a life cycle period of about two weeks. It is apparent therefore that a steadily increasing quantity of decomposing organic matter from these micro-organisms and vegetation will accumulate in a reservoir during warm weather. This decomposition is usually the underlying cause of seasonal taste, due to the liberation of minute traces of obnoxious volatile oils. Depending somewhat upon the species, from 500 to 1,000 units per cc. will produce taste in drinking water. This does not mean that the counts found at the water plant may be taken as the index of trouble. If the water is obtained from reservoirs, large lakes, or rivers, the number of micro-organisms at some point upstream, corresponding to a flow of about 2 weeks, is of great significance in estimating possible taste problems. A high concentration of organisms in this locality will produce decomposition products with subsequent taste when the water reaches the plant intake. Sampling stations located at various points in the reservoir are required for good algae control.

Copper sulfate in low concentrations is extensively used as an algaecide. Dosage varying from 0.1 to 5.0 ppm. is effective. It may be applied by spraying the water surface with mechanical equipment or by dragging a pervious bag through the water by boat.[13] Fish life may be poisoned unless reasonable care is exercised. A dose of 0.14 ppm. will kill trout but black bass can tolerate 2.0 ppm., with limits for other common species between these limits. Use of copper sulfate in these minute doses has no effect upon the human system. It has been established that 5 ppm. will give a disagreeable taste but that 20 ppm. per day is not dangerous to health. Recent investigations indicate that the usual coagulant (such as alum) absorbs this compound; therefore it will not be present in the water delivered by a purification plant and is only a problem when unfiltered water is used.

## WATER PURIFICATION AND TREATMENT

Water may be treated in various ways and for different purposes. It is of paramount importance to public health that treatment assure a supply free of pathogenic organisms. Further treatment to remove tastes, odors, or colors has distinct esthetic values and indirect public health significance in that a clear, tasteless, odorless, and colorless water is more palatable than one showing turbidity or having an objectionable taste or odor.

The secondary type of treatment in such cases would be aimed at the maintenance of a uniform level of taste or odor. To these two types of treatment can be added a third, that of corrective treatment for the elimination of corrosiveness or objectionable hardness. This last type usually has only economic significance.

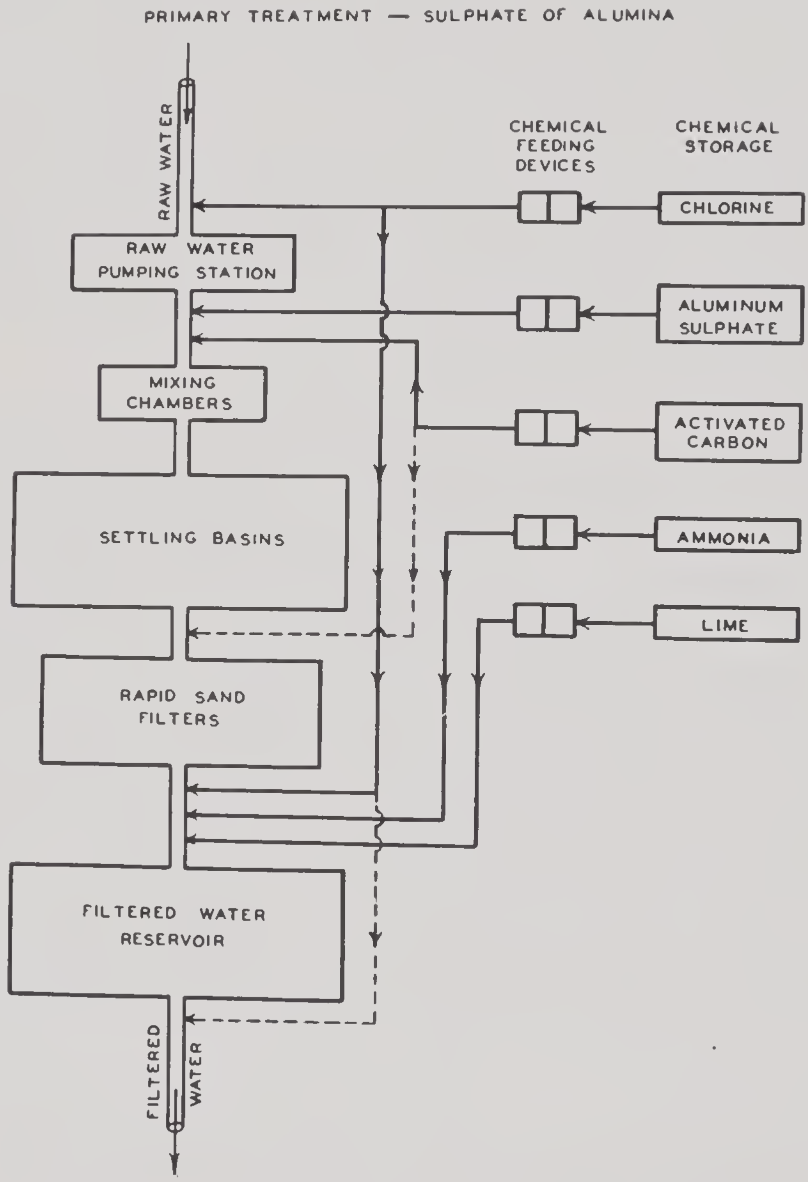



Fig. 30. Conventional flow diagram for water purification

Present day methods of purification have been developed through the accumulation of experience and study over many years and include certain fundamental principles—namely:

Storage in natural lakes or impounding reservoirs to obtain sedimentation.
Coagulation by chemical treatment for the removal of turbidity and color.
Sedimentation of the coagulated floc to minimize the quantity of suspended and colloidal matter on the filter beds.

Filtration through sand and gravel beds to remove turbidity and many micro-organisms.
Disinfection by chemical or physical agents to eliminate pathogenic bacteria.
Removal of taste or odors by aeration, chemical treatment, or physical adsorption to make the water more attractive.
Hardness reduction by chemical precipitation or base exchange phenomenon for esthetic and economic reasons.
Removal of dissolved minerals by surface adsorption (contact beds) generally for esthetic reasons.
Corrective treatment with alkali to reduce pipe corrosion for economic reasons.

The type and degree of purification is governed by the characteristics of the raw water and by economic factors. The value to a community of adequate purification far surpasses the installation and operating cost. Whatever degree of treatment is adopted, a safe supply must be the minimum accepted.

## Plain Sedimentation

When used for a water supply without impounding reservoirs, large rivers such as the Mississippi, Ohio, Red, Missouri, and Colorado require artificial sedimentation to remove the great amount of silt held in suspension. Turbidities in these major rivers average 2,500 ppm. with maxima above 60,000 ppm. Sedimentation in large basins for about 12 hours will reduce these high turbidities below 1,000 ppm. These basins are occasionally built with special hopper bottoms to permit the continuous flushing of the settled sludge to the sewer. Mechanical clarifiers, consisting of slowly moving scrapers, are frequently used to scrape the mud into a center sump or into side gutters from which it is removed by flushing or pumping. These basins would be impractical without some system of continuous sludge removal since the rapid accumulation of solids would fill them in a few days. Boulder City, Col., Kansas City, Mo., and St. Louis, Mo. are the best known plants using this pre-treatment.

## Filtration

Filtration of water may be defined as the removal of suspended material to give complete clarification. Sand beds are the most common media used, although beds of crushed anthracite coal and crushed quartz are also employed. Filters may be operated under the influence of gravity or may be connected into a pressure system. Pressure filters are adaptable to small installations.

Gravity filters are divided into rapid and slow sand units. The rapid sand unit normally filters at a rate of 2 to 3 gallons per square foot per minute or 125 to 190 million gallons per acre per day. A slow sand filter will successfully clarify 0.06 gallons per square foot per minute or from 3 to 6 million gallons per acre per day.

### *Slow Sand Filters*

The slow sand or "English" filter will satisfactorily clarify waters of low turbidity without the aid of chemical coagulants. It is not adaptable to muddy water and prior sedimentation in very large reservoirs is required for efficient operation. These filters are not practicable if the raw water carries more than 30 ppm. of turbidity. In situations of low turbidity where prior treatment is unnecessary, highly skilled operators are not required and the filters are therefore economical to operate. Large land areas must be available.

Raw or settled water is passed directly to these filters, each about 0.5 acre in area. The sand beds are from 24 to 48 inches in depth, overtopping a graded gravel bed from 12 to 24 inches deep, which is supported by a brick or tile underdrain system. The top sand is between 0.20 and 0.30 mm. in diameter and a constant flow is maintained through the beds by aid of mechanical devices or manual manipulation of the effluent valves.

Good bacteria and turbidity removal are obtained with these filters after a colloidal slime, known as *schmutzdecke*, has accumulated on the sand grains. This coating entraps all suspended material, clarifying the water by biological and mechanical action. Using gravity flow, the top portions of the beds become clogged first and are cleaned by scraping from 1 to 2 inches of sand from the surface. This sand is mechanically washed and restored to the bed. Sand washing machines have been developed that rake and wash the sand surface without removal from the beds, saving considerable time and labor.

The filtered water is usually disinfected with chlorine. There is little or no biological activity, and bacterial removal is poor with cold water of about 40° F. temperature.

The disadvantage of this type of plant is in its inability to purify muddy water, and the limited use of each bed between cleanings. The development of the rapid sand filter has more satisfactorily met modern demands for effective operation with all types of water. The chief advantages of the slow sand filter are its economy and simplicity of operation.

Slow sand filters are in service at many places. Washington, D. C., Philadelphia, Pa., Pittsburgh, Pa., Hartford, Conn., Poughkeepsie, N. Y. and Lawrence, Mass. are the most important in the United States.

### *Rapid Sand Filtration*

The greater volumes of water passed through the rapid sand unit in comparison with the slow sand unit is made possible by the use of larger sized sand grains, 0.40 to 0.50 mm. diameter, in the beds and by coagulation of the very fine suspended particles in the water with chemical compounds. This coagulated material immediately coats the sand with a

highly absorbent, gelatinous hydrous oxide floc, forming an artificial *schmutzdecke* that makes possible rapid clarification. The effective cleaning of these beds by a high velocity backwash, requiring only a few minutes, gives a more or less continuous use of these units at high efficiency.

## Coagulation

Coalescence of the finely divided colloidal turbidity or color particles into a gelatinous mass, called floc, by certain chemicals is known as coagulation. Alum, sodium aluminate, ferrous sulfate with lime, chlorinated copperas, ferric chloride and ferric sulfate are good coagulants. Alum is the one used most extensively. Colloidal silicate and certain clays such as bentonite are being increasingly utilized as "coagulation aids."

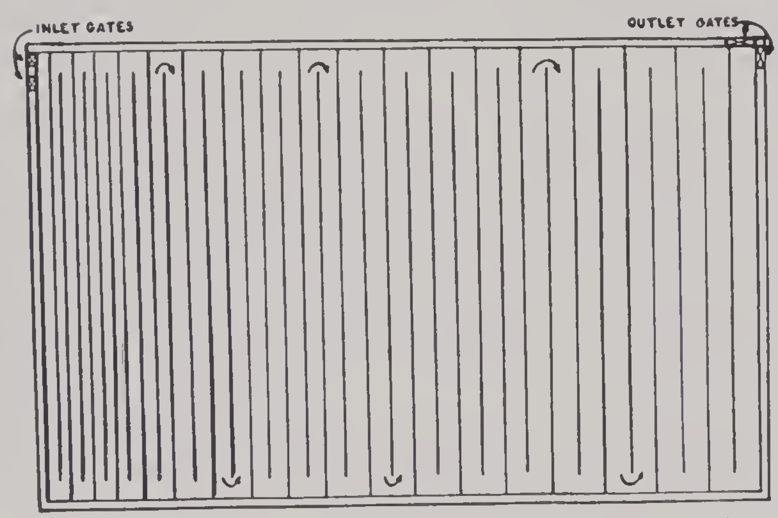



Fig. 31. Typical "around the end" mixing basin

### *Mixing*

Since floc formation results from the conglomeration of colloidal particles, mixing of these particles throughout the water is necessary. Improperly formed floc is occasionally found because of faulty mixing basin design. The efficient mixing basin provides a high velocity, and rapid mixing of the coagulant through the water with baffles or agitators arranged to provide gradually decreasing speeds throughout the remaining portion of the basin. A certain length of time and a definite minimum velocity in mixing must be observed to produce compact floc particles

This particle coalescence is in accordance with the von Weimarn theory, namely that crystal growth is either a coalescing of smaller crystals into larger ones or a clumping of them into larger groups. Since colloidal particles do not readily diffuse, rapid aggregation of them into clumps is possible by agitation which is induced mechanically.[3]

Various types of mixing devices are employed. Baffled basins are the most frequently used. This may be either the "around the end" type in

which the water flows in a series of narrow deep channels with 180° turns at each end, or the "up and down" installation in which the water is made to travel from the bottom to the top of the basin in regular sequence by a succession of baffles. The "around-the-end" type of baffled basin is generally found in the larger plants, with rates of 25 million gallons or more per day, and the "up and down" baffles in the smaller.

In addition to baffled basins the "hydraulic jump", compressed air and spiral baffled tangential basins are used. Frequently, raw water pumps serve as the mixing device. Special high speed "flash mixers" are on the market. Combined mixing-settling basins, utilizing the principle of an upward flow of coagulated water through the settled sludge, known as sludge blanket devices, are recent developments.[12] The "Flocculator" when installed in the inlet side of the sedimentation basin may be considered as an auxillary mixing device. It is also used following flash mixing to produce floc conglomeration and when so utilized, replaces the conventional mixing basin.

### *Floc*

Properly coagulated floc is a compact material as shown by the microscopic drawings in Figure 32. In section *B* the fine particles have coalesced forming a definite flocculation with an even distribution of suspended silt throughout the mass. This material is concentrated into the floc particles, giving toughness and density, to secure good sedimentation and filtration. Insufficiently coagulated particles will not readily settle and will pass through the filter beds. The physical properties of floc are dependent upon the conditions of mixing, while the chemical characteristics are a function of the hydrogen ion concentration (pH value) at which the reaction occurs.

Floc is the impure hydrous oxide of the metallic salt used as the coagulant. The normal reactions occurring in coagulation are:

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 \rightarrow Al_2O_3 \cdot 3H_2O + 3CaSO_4 + 6CO_2$$

$$4FeSO_4 + 2Ca(HCO_3)_2 + 6Ca(OH)_2 + O_2 \rightarrow 2Fe_2O_3 \cdot 3H_2O + 4CaSO_4 + 4CaCO_3 + 2H_2O$$

$$Fe_2(SO_4)_3 + 3Ca(HCO_3)_2 \rightarrow Fe_2O_3 \cdot 3H_2O + 3CaSO_4 + 6CO_2$$

$$2FeCl_3 + 3Ca(HCO_3)_2 \rightarrow Fe_2O_3 \cdot 3H_2O + 3CaCl_2 + 6CO_2$$

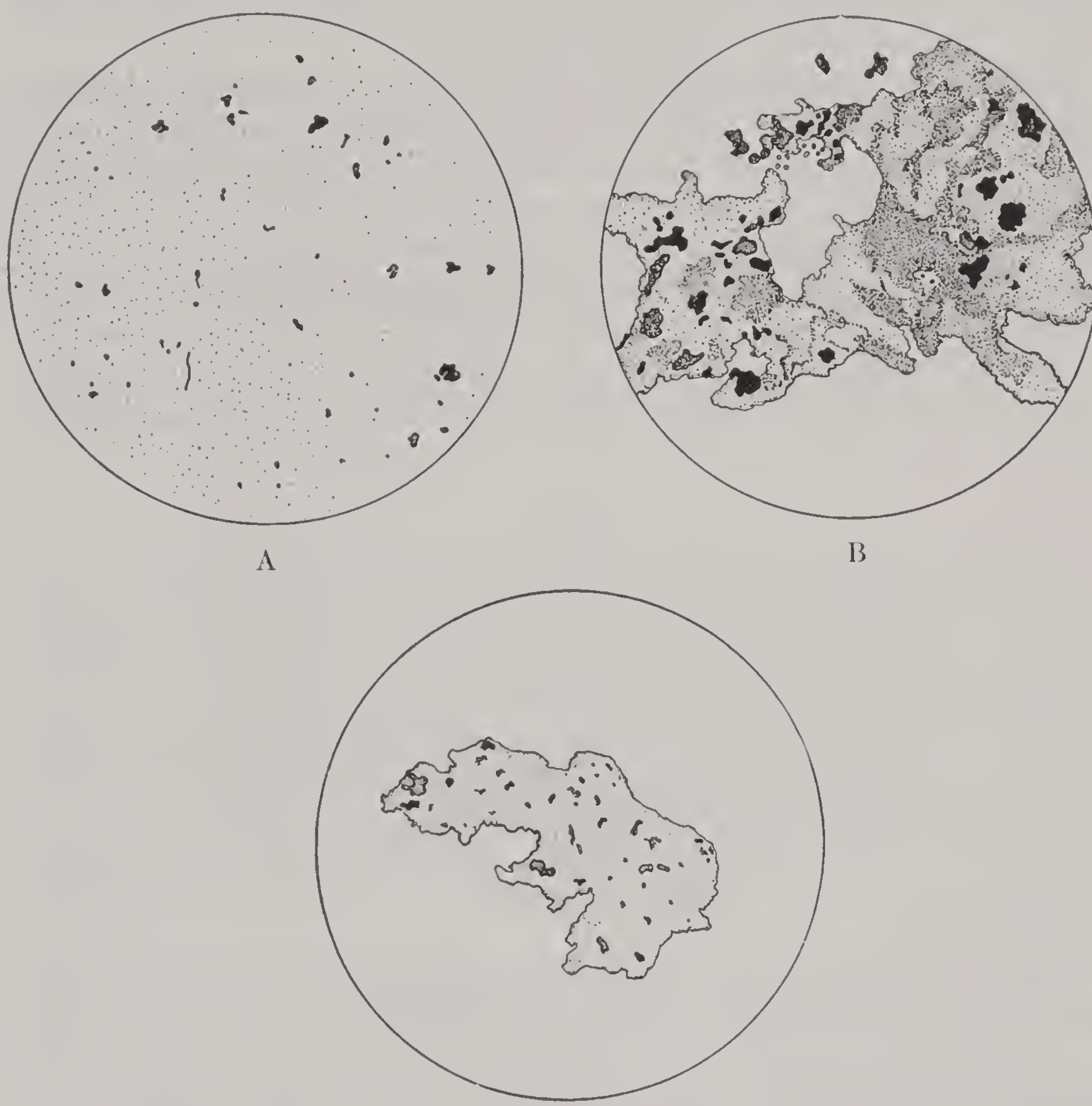
$$6FeSO_4 + 3Cl_2 \rightarrow 2FeCl_3 + 2Fe_2(SO_4)_3 \text{ or}$$

$$6FeSO_4 + 3Cl_2 + 9Ca(HCO_3)_2 \rightarrow 3CaCl_2 + 6CaSO_4 + 3Fe_2O_3 \cdot 9H_2O + 18CO_2 \text{ or}$$

$$Fe_2(SO_4)_3 + 2FeCl_3 + 6Ca(HCO_3)_2 \rightarrow 2Fe_2O_3 \cdot 3H_2O + 3CaSO_4 + 3CaCl_2 + 12CO_2$$

Most natural waters are alkaline from the dissolved bicarbonates of

calcium and magnesium. Trade wastes or acid mine water may neutralize this alkalinity. Since the coagulating reactions are essentially the formation of metallic hydrated oxides, there are definite concentrations of alkalinity that must be obtained for optimum floc formation. These con-



A

B

C

Fig. 32. Microscopic drawing of floc

ditions are different for each coagulant used. Increased alkalinity is obtained by the addition of lime or soda ash.

*Control of Hydrogen Ion Concentration*

Upon addition of the coagulant to the water an acid-alkaline balance is quickly established and does not change with the physical characteristics of floc formation. This ratio between acid and alkaline characteristics is measured by the hydrogen ion concentration (pH).

It is assumed that a discussion of the principles underlying hydrogen ion concentration or pH value is unnecessary in this text. Since pure water is neutral and the dissolved salts and gases give it acidity or alkalinity with or without buffer action, it is apparent that pH value is not a measure of the *total* alkalinity or acidity of a water, but of the intensity of its acidic or alkaline properties. Waters containing the largest amount of dissolved material usually have the greatest buffer action. They therefore will combine with a larger quantity of acid or alkali before changing in pH value. Their alkalinity or acidity is determined in the usual manner by methyl orange and phenolpthalein titrations.

Maximum precipitation of alum floc in plant operation varies from a pH value of 6.0 to 7.2 in accordance with the buffer action of the dissolved salts in different waters. Soft waters coagulate at the lower values while hard, alkaline waters flocculate best above neutrality.

Iron floc coagulated from ferrous sulfate by the addition of lime reaches maximum precipitation at pH 9.4. Good turbidity removal is obtained between pH values of 8.8 to 9.2 which is a practical operating range. A compact floc is obtained at any pH value above 3.5 with ferric salts.

### *Coagulation "Aids"*

Silica precipitated from sodium silicate solutions is being introduced as a "coagulation aid" under specific conditions. When of economic advantage, a tough, compact, readily settling floc is produced that will give increased filter runs.

### *Coagulation Control*

The amount of coagulant required to form floc varies with the turbidity, organic material, color colloids and buffer action of the dissolved minerals in the water. The dosage to be used in the plant is determined by stirring a test sample in the laboratory with mechanical devices, using varying amounts of chemical (jar test). Figure 33. The lowest concentration forming compact floc is the amount that will be satisfactory in the plant. Table 11.

The coagulating chemicals are usually applied in a solution through a graduated orifice from storage tanks or by proportionating pumps. Figure 34. The smaller plants frequently feed the powdered material directly to the water through mechanical "dry feeders". Figure 35. Accurate control may easily be maintained by either method with a minimum of operating error.

### *Sedimentation*

Sedimentation as a function of filter plant operation is understood to mean the deposition of floc, formed by chemical coagulation, in basins

designed for this purpose. The rectangular basin with a horizontal flow of water may be considered as conventional but upward flow basins in

FIG. 33. Laboratory flocculating device. (Courtesy, Omega Machine Co.)

TABLE 11

*"Jar Test" to Determine Optimum pH value and Minimum Dose of Coagulant to Be Used*

| Raw Water | | G.P.G. Alum | G.P.G. Lime* | pH after Mixing | Coagulation Characteristics |
|---|---|---|---|---|---|
| Turbidity | pH | | | | |
| *ppm.* | | | | | |
| 12 | 6.8 | 0.2 | | 6.7 | None |
| | | 0.3 | | 6.7 | Fair |
| | | 0.4 | | 6.6 | Good |
| | | 0.5 | | 6.6 | Good |
| | | 0.7 | | 6.4 | Heavy floc |
| | | 1.0 | | 6.2 | Heavy floc |
| 18 | 4.0** | 0.4 | 1.0 | 4.5 | None |
| | | 0.4 | 2.0 | 4.9 | None |
| | | 0.4 | 3.0 | 5.8 | Fair |
| | | 0.4 | 3.5 | 6.0 | Fair |
| | | 0.4 | 3.7 | 6.4 | Good |
| | | 0.4 | 4.0 | 6.8 | Good |

* Caustic or soda ash may be substituted.

** Below optimum pH value as shown by previous test.

Note: Amount of alum as given by the test at the optimum pH value is 0.4 g.p.g. Optimum pH value shown to be at 6.6.

Using the values found for the normal water the test indicates that 3.7 g.p.g. lime will produce good floc and give the optimum pH of about 6.5, when acid water is present.

which the clarified water passes upwards through a blanket of suspended sludge have been developed.

FIG. 34. Chemical solution feeder. (Courtesy, Proportioneers, Inc.)

FIG. 35. Dry chemical feeders, Dallas, Tex. (Courtesy, Omega Machine Co.)

The conventional basins are designed upon the premise of maintaining the flow through them at a velocity too low to retain the coagulated

particles in suspension. This flow should not be greater than 1 foot per minute. A well designed basin will remove sand within 2 hours and flocculated material within 4 hours. Figure 36. Sedimentation basins may be

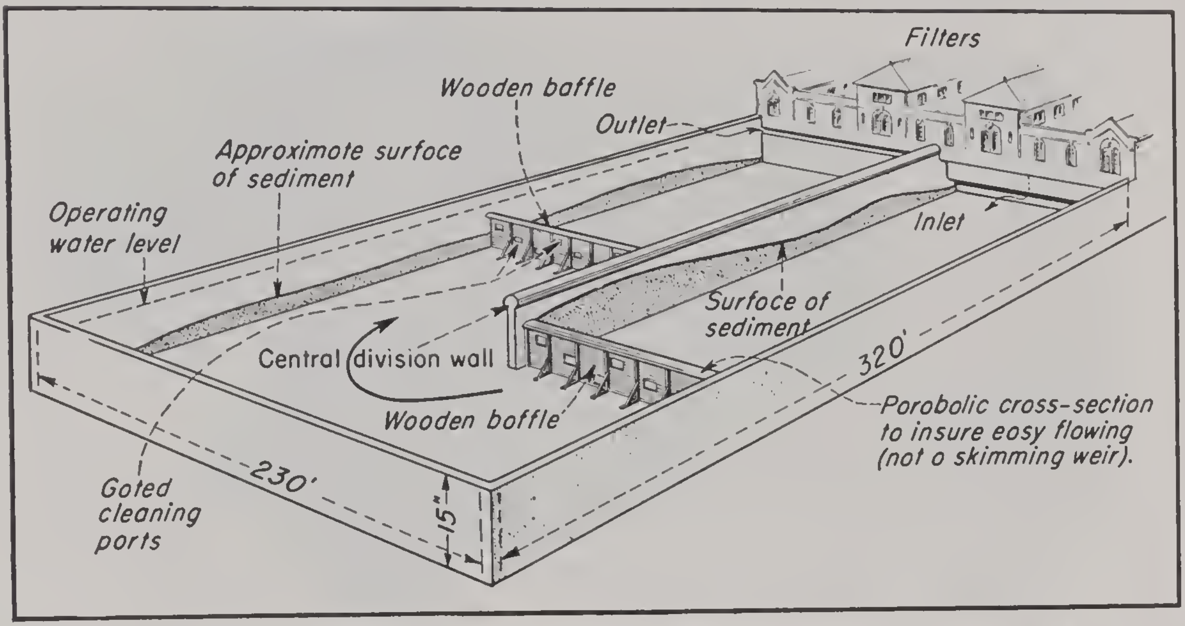



FIG. 36. Profile of silt deposited in sedimentation basin. (Courtesy, Engineering News Record.)

FIG. 37. Manual cleaning of sedimentation basin, Baltimore, Md.

operated in series, provided the floc is not broken by excessive velocities when passing through control gates and connecting conduits. Poorly designed and therefore improperly functioning basins will decrease filter efficiency since a large amount of suspended material will pass through them increasing the amount that must be removed in the filters.

The accumulated sludge, unless removed by ejectors or mechanical methods, is periodically cleaned from the basins by manual labor using streams of water from hoses for flushing purposes. This is done at least twice yearly to decrease the effect of decomposition of organic matter in the sludge.

Sludge blanket devices are a combination of mixing basin and settling tank designed to bring the unstable suspended precipitates into equilibrium quickly. They are based upon the principle of mixing the micro-crystals of

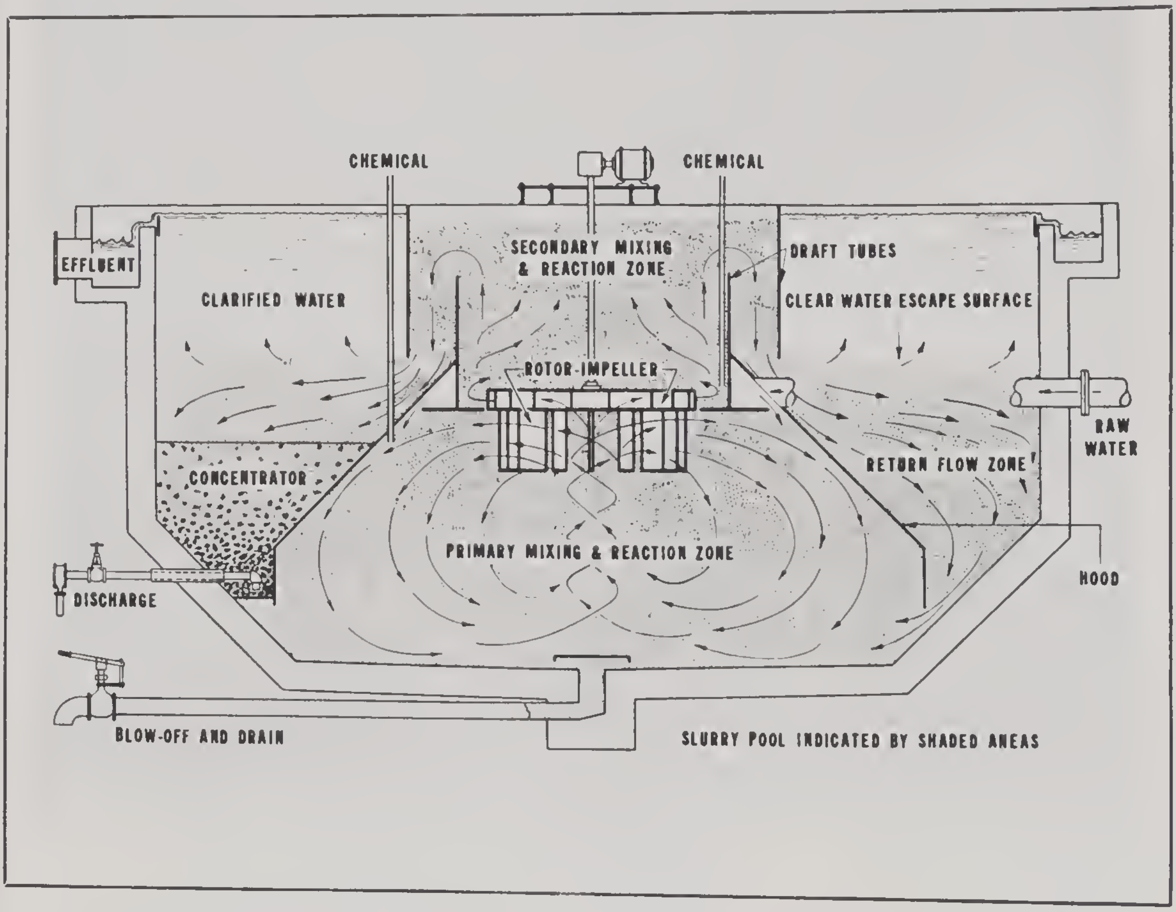



Fig. 38. The Accelator. (Courtesy, Infilco, Inc.)

previously precipitated conglomerates to create a rapid growth of particles by precipitating the supersaturated colloids upon them. Clarification is accomplished by the mechanical straining action of the suspended sludge blanket. Figure 38.

## Efficiency of Filtration

The theory that filtration is the primary defense against disease is no longer true. It is now recognized that coagulation and sedimentation are the primary factors controlling the operation of a purification plant, and that filtration through sand beds produces the clarified water desired by the public. Without prechlorination it has been observed that although

the effluent is clear, organisms will multiply rapidly in filter beds. With the general utilization of prechlorination (addition of chlorine in the early steps of water treatment as contrasted with the addition to the final, clarified product) bacterial growth in filters has been overcome. Chlorination is no longer considered as secondary defense treatment but one of the primary factors in water purification. This is a reversal of the time honored relationship.

FIG. 39. Filter gallery No. 2, South District Filtration Plant, Chicago, Ill. (Courtesy, John R. Baylis.)

The average gravity flow, rapid sand filter, is designed to function at the rate of 2 gallons per square foot per minute. A series of units is arranged in a gallery with each unit capable of independent operation. Figure 39. A diagrammatic outline of a filter unit is shown in Figure 40.

The underdrains of hollow tile, perforated pipe, fused alumina plates or manifold bronze strainer plates form the bottom of the filter unit. A bed of graded gravel varying in size from $\frac{1}{8}$ inch diameter at the top, to 2 inches at the bottom, is placed over this system to a depth of about 20 inches. This is topped by a sand bed, approximately 2 feet thick, having the smallest grains about 0.50 mm. diameter. If coal (Anthrafilt) is substituted for sand, similar sizes and depths are used.

The coagulated water is filtered by downward flow through the beds,

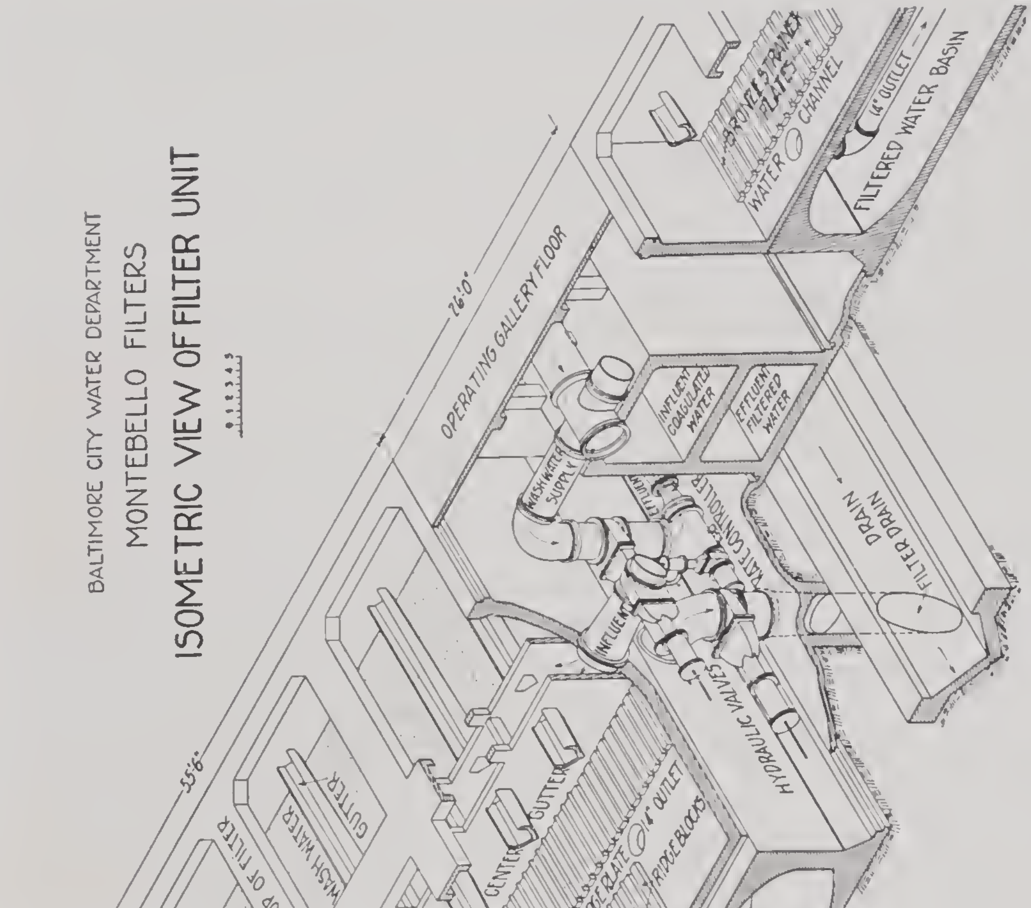



Fig. 40. Isometric view of filter unit

with deposition of the floc particles upon the sand grains, eventually filling the voids between them. The top few inches of the sand bed serves as the filtering medium. When fine sands, less than 0.40 mm. diameter, are used, a compact mat forms at or near the surface. With coarse sand grains, the floc masses slowly penetrate into the bed for considerable depths, permitting long operating periods between backwashing. The rate of flow through a filter should always be at uniform velocity and never be suddenly increased. Sudden variations in rate may seriously rupture the mat of deposited material and cause floc to pass through the bed.

Water passing through a sand bed encounters a certan amount of resistance due to friction. This is increased by the accumulation of deposited material. After an extended period of service the pressure required to force water through the bed is equal to that exerted by the height of water above the bed. This frictional pressure is known as loss of head and increases directly with the rate of flow. At normal rates of flow when the units are in constant service the operating period will vary from 20 to 50 hours between washings. Sudden temperature changes may entrap air in the beds with a resulting increase in resistance to the flow of water. Unusually heavy densities of micro-organisms will clog the beds, necessitating more frequent washing. The loss of head is the criterion upon which the need for washing is determined. However, when fully trained operators are not on duty at all times it is common practice to establish a fixed time interval between washings.

Constant filtration rates are maintained by mechanical controllers which automatically open the effluent valve wider as the loss of head increases. Uniform flow may also be obtained by the insertion of a fixed orifice disc in the effluent line or by opening the effluent valve to a fixed point.

Filtered water turbidity should not exceed 0.5 ppm. Various devices to determine turbidity or to detect floc particles passing the sand beds have been designed. They are based upon the well-known Tyndall light beam, used in microscopic and projection work. Another common method of turbidity measurement consists of a comparison of the filtered water with samples of water to which known quantities of Fuller's earth have been added.

*Washing*

When the loss of head reaches some predetermined value, usually a height of about 8 feet, or if floc passes through the bed before this pressure is reached, the filter is backwashed by stopping the flow of water downward through the filter and admitting water at high velocities to the bottom of the filter through the underdrain system. The rates vary between 18 and 30 gallons per minute per square foot of filter area. The sand bed is sus-

pended by this high velocity wash water and expands from 30 to 50 per cent of its depth. This rapid flow agitates the sand grains producing a scouring action that removes incrusted material which is carried off in the drain troughs. Sand is not lost as the spacing and height of the troughs and rate of backwash permit only the lighter mud particles to flow into them. With the release of backwash pressure the normal sand bed grading is reestablished with the coarsest grains settling out first and the finest particles last on the top. Although the wash water enters the filter bed through the numerous openings in the underdrain system, even distribution is produced by the fine gravel underlying the sand. Therefore proper grading of the gravel bed during construction is of extreme importance to filter washing. Many troubles arise from the improper depth and size of the fine gravel layer.

Poorly washed beds will leave dirty sand grains that stick together forming impervious masses or "mud balls" about the size of acorns. These masses are of sufficient density to drop to the top of the gravel layer through the expanded bed during the washing period. They gradually accumulate in this region and build large localized mounds and ridges which considerably reduce the efficiency of the filter. When present they must be removed by manual labor with an increase in maintenance costs.

Auxiliary mechanical surface washing devices which thoroughly scour the top portion of the filter bed have been developed. This scouring effect breaks up mud balls. This action may be obtained by jets of water at high pressure or by streams of air directed into the top few inches of the sand bed. Water if used is usually supplied from the distribution system or other auxiliary sources of the backwashing system.

When used in conjunction with good sand expansion under the influence of the backwash, mechanical surface wash will thoroughly clean sand, Anthrafilt, or beds of other media.

The rate of filtration, temperature of the water, loss of head, and backwashing are the important features of filter operation.

### *Pressure Filters*

The general construction and operation of these units is essentially the same as for gravity filters. Figure 41. They are operated under pressure with the filter medium enclosed in steel tanks and the water forced through the bed. The maximum rate of filtration is limited to standard flows, but actually is controlled by the volume of water passing through them. When the filters become dirty, they are backwashed as are gravity filters. Sand sizes vary from 0.30 to 0.40 mm. diameter and the beds have normal depths, overtopping the gravel layer with perforated pipe under drain systems. These filters find general application in secondary industrial and swimming

pool installations, although a few small domestic treatment plants have found it economically advantageous to install them for water supplies.

### Taste and Odors

It is difficult to distinguish between taste and odor since these senses are so closely related. In the discussion of control procedures the contaminants producing taste and odors will be considered without differentiation.

Sources of tastes and odors are found in heavy infestations of micro-organisms and trade waste pollution from coke oven wastes, discharge

Fig. 41. Pressure filter unit. (Courtesy, The Permutit Co.)

from creosoting works, gas plants and oil refineries, and other industrial operations. Occasionally trouble results from the use of pipe lines and tanks protected by some types of coal tar paints which impart tastes and odors. It is characteristic of many industrial wastes that the amounts discharged by these industries are not particularly objectionable until the water is chlorinated. The chlorophenols, produced by the addition of chlorine to water carrying phenolic wastes, in which the chlorine has replaced either the hydroxyl radical or has split off the hydrogen of the original compound, are the worst offenders.

The most common origin of taste in a water supply is the decomposition of dead micro-organisms, especially algae. Excessive concentrations of these organisms frequently occur during periods of warm water and, if

killed by chlorine disinfection or copper sulfate treatment, may produce obnoxious tastes. These tastes may develop when algaecides are not used because of the enormous number of dead organisms that occur through natural causes.

*Control*

**Chlorine.** It is generally assumed that a count of 500 organisms per ml. will cause taste when prechlorination is used and that without this treatment greater concentrations may be troublesome. The powerful oxidizing properties of chlorine are used to break down these organic compounds into simpler tasteless products by the addition of more chlorine than is required as a bactericide. This action is produced by superchlorination. Chlorine is the cheapest oxidant available. With precise measurement of the free residual concentration, oxidation of taste producing chemically unstable trade wastes and organic compounds from vegetation and microorganism decomposition is practical. Stable chemical compounds such as oil refinery wastes, will not be oxidized.

As explained on page 164, by use of the Laux "flash" test and the Hallinan ortho-tolidine-arsenite determination, chlorination may be accomplished without the formation of taste producing volatile chloro-substitution compounds. A palatable water will in many instances be produced when a contact period of 4 to 6 hours is available for either pre or post chlorination.

Superchlorination is used for short contact periods. It may be defined as the use of "such high doses as to require the subsequent use of a dechlorinating agent."[4] Dechlorination to remove chlorine taste is usually accomplished with sulfur dioxide or activated carbon.

**Chloramines.** The use of chloramines for taste control has to a large degree been superseded by either the breakpoint or superchlorination treatment. Chloramines are of value as inhibitors for chloro-phenol tastes. They will not destroy the phenol waste but do prevent the intensification of taste from these products upon chlorination. This attribute is due to the slow release of hypochlorous acid with the nascent oxygen not readily reacting with the hydroxyl radical in the phenol molecule.

**Chlorine Dioxide.** The use of chlorine dioxide for the control of tastes and odors is being extensively investigated. This material is an unstable gas, soluble in water, and when compared on an available chlorine content, has an oxidizing capacity 2.5 times greater than chlorine. Its development has been made possible by the commercial production of sodium chlorite. This powerful oxidant ($ClO_2$) will destroy all organic material and when economically justified, is practical for taste removal.

**Aeration.** Aeration of water removes tastes and odors by sweeping out

the dissolved gases which are then replaced by oxygen from the air. The water may be forced through nozzles into the air as a fine spray, allowed to cascade over an irregular surface from a pre-determined height, or air may be mechanically drawn into it under pressure. The dissolved gases and light volatile oils are mechanically removed by the spray of very fine bubbles, while the chlorinated organic compounds are partially oxidized by the treatment. Aeration cannot be expected to remove taste from phenol wastes or algae decomposition products, but will remove excess chlorine and reduce chloro-compounds.

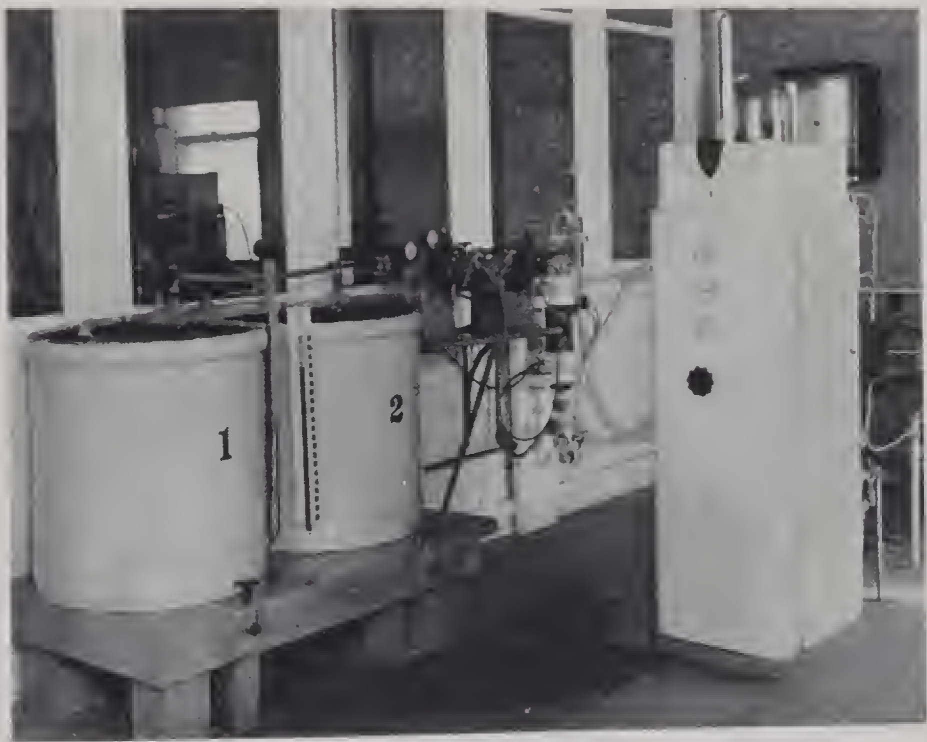



Fig. 42. Chlorine dioxide generating equipment. (Courtesy, Mathieson Chemical Co.)

**Activated Carbon.** Activated carbon is a valuable adsorbent of taste producing compounds. It is utilized in many plants by adding the powdered material to the water before filtration. Special equipment is not necessary for feeding it. The carbon must be intimately mixed with the water and allowed the greatest possible time of contact before filtration. It is usually applied with the coagulant in the mixing basin.

Tastes and odors due to organic substances may be removed by heavily chlorinating the water initially to break down the organic compounds. This treatment is followed by the addition of activated carbon in the mixing basin, resulting in the adsorption of the chloro-compounds. Subsequent entrapment of the carbon in the floc, and removal by sedimentation and filtration is effective. It has been demonstrated that these chloro-compounds are more easily adsorbed than the original materials.

The continued use of powdered activated carbon in conjunction with prechlorination and superchlorination will be an interesting development of the future. Concentrations of activated carbon required to remove taste successfully vary from 0.6 to 10.0 ppm. Since waters possess different characteristics, which frequently change from day to day, only trial with empirical dosage will determine the proper concentration to use.

Granular activated carbon filtering units for small installations, 500 gallons per minute or less, are often placed in service lines in food manufacturing establishments. A few municipal plants have installed gravity filters of this material.

### *Public Health Effect of Taste*

A palatable water is essential for public consumption. Water having a disagreeable taste or odor will cause consumers to drink from sources other than the public supply. In some instances these sources are not bacterially safe. It is apparent therefore that a public supply which frequently has a bad taste is a potential health hazard. In addition, the quantity of water drunk may be curtailed, with the substitution of less desirable beverages. Tastes and odors are always undesirable from an esthetic point of view.

## Iron and Manganese Removal

Many water supplies contain quantities of iron and manganese that cause them to be unsatisfactory for domestic or industrial use without treatment. Iron has long been recognized as an impurity of ground waters. Manganese is more commonly present in both ground and impounded surface waters than is generally realized.

Waters containing less than 0.2 ppm. of iron and manganese are not objectionable to the average consumer. Higher concentrations deposit stains on white enamel fixtures and on clothes washed in the water. The presence of these hydrous oxides in a water supply will also cause complaint from bottlers, commercial laundries, paper mills, and ice manufacturing plants. The unstable manganese oxides produce a false orthotolidine color which interferes with the residual chlorine test[12] in water examinations. The taste imparted by iron salts is objectionable to many people.

In ground water supplies these elements are held in solution as bicarbonates by the dissolved carbon dioxide. Surface supplies may intermittently show excessive manganese concentrations when impounded in deep reservoirs. This manganese is extracted from the bottom muck by the dissolved carbon dioxide in the bottom water. The carbon dioxide is produced by an anaerobic fermentation of the vegetation deposited on

the bottom of the reservoir. Active fermentation takes place when the temperature of the bottom water is above 68° F. and is accompanied by a gradual reduction in the dissolved oxygen. This decomposition progressively releases carbon dioxide. Manganese compounds are converted into manganous bicarbonate and retained in solution.

With equilization of top and bottom water temperatures below 59° F. in the autumn "seasonal turnover" the soluble manganese is distributed throughout the water and is converted to hydrous oxide by the dissolved oxygen available in the surface layer of the water. This increase in dissolved oxygen checks the anaerobic decomposition and the manganese density becomes of negligible importance until the next period of warm water.

Since iron and manganese are generally held in solution as the bicarbonate by the dissolved carbon dioxide, aeration is used to release the gas. The oxygen introduced will partially precipitate the iron and manganese as hydrous oxides. The process also removes other volatile gases such as hydrogen sulfide. The aeration is followed by 6 hours of sedimentation and sand filtration. High concentrations of iron are reduced to less than 0.1 ppm. by this method. When removal of all carbon dioxide is desired, it must be neutralized with lime or other alkali before filtration through the sand beds. Manganese is more difficult to precipitate than iron.

About 0.14 ppm. of oxygen will precipitate 0.1 ppm. of iron; 0.29 ppm. is required for 1 ppm. of manganese. The reactions are:

$$Fe(HCO_3)_2 + H_2O \rightarrow FeO \cdot H_2O + 2CO_2 + H_2O$$
$$4FeO \cdot H_2O + 2H_2O \rightarrow 2Fe_2O_3 \cdot 3H_2O$$
$$2Mn(HCO_3)_2 + H_2O \rightarrow 2MnO \cdot H_2O + 4CO_2 + H_2O$$

The hydrous manganese oxide formed initially by aeration will rapidly oxidize to a manganic oxide ($Mn_3O_4$) and then be slowly converted to $Mn_2O_3$ as the final product.

Contact beds of coke, stone, or large gravel, usually arranged in a series of trays, from 12 to 16 inches deep, with perforated bottoms, form effective aerators for the precipitation of these compounds. These beds are operated at high rates, 15 to 20 gallons per square foot per minute. Apart from serving as efficient aerators, they also precipitate the colloidal oxides by the powerful catalytic oxidizing action of the previously deposited manganese dioxide or ferric oxide coating in the beds.

The most modern plant operating upon these principles for the removal of iron and manganese has been constructed at Lincoln, Neb.

Chemical precipitation of these elements with lime, usually in conjunction with ferrous sulfate coagulation, is very effective. Their iso-electric

points are at pH 9.4, making possible quantitative removal of them in accordance with these reactions:

$$4Fe(HCO_3)_2 + 8Ca(OH)_2 \rightarrow 2Fe_2O_3 \cdot 3H_2O + 8CaCO_3 + 6H_2O$$
$$2Mn(HCO_3)_2 + 4Ca(OH)_2 + 2O_2 \rightarrow 2MnO_2 \cdot H_2O + 4CaCO_3 + 4H_2O$$

Therefore coagulation followed by sedimentation and filtration will produce a water free from these elements.

A special zeolite filter functioning at 20 gallons per square foot per minute, has been developed to remove iron and manganese by base exchange reaction. The plant at East Lansing, Mich., is a typical installation.

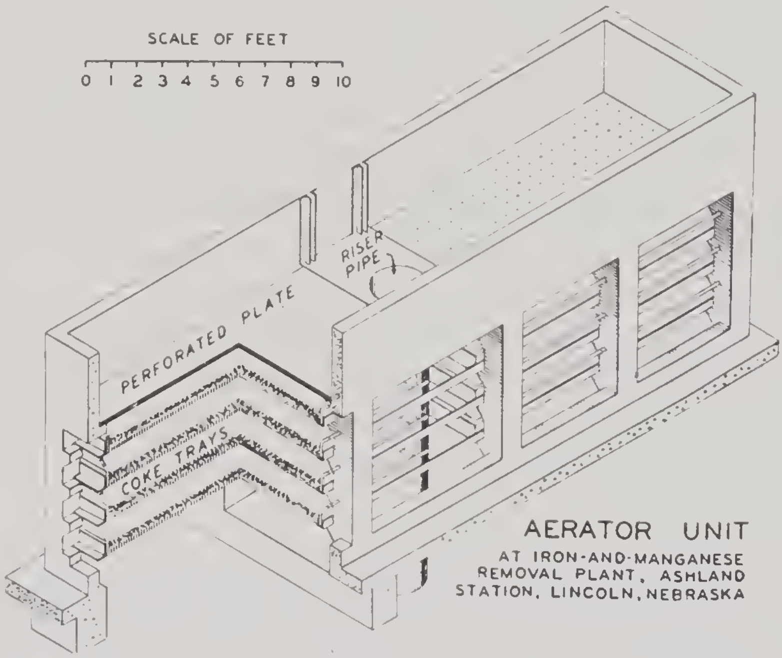



Fig. 43. Coke bed aerator, Lincoln, Neb. (Courtesy, D. L. Erickson.)

Precipitation of manganese by use of superchlorination is practical, provided a sufficient dosage is applied to destroy all organic material and to oxidize the manganese to an insoluble oxide. This may be accomplished by maintaining a free residual chlorine concentration of not less than 0.5 ppm. in the filtered water. These reactions are:

$$Cl_2 + H_2O \rightarrow 2HOCl + 2HCl$$
$$6MnO + 2HOCl \rightarrow 2Mn_3O_4 + 2HCl$$
$$4Mn_3O_4 + 2HOCl \rightarrow 6Mn_2O_3 \cdot 2H_2O + 2HCl$$

with the hydrochloric acid neutralized by the calcium bicarbonate present in the water.

This procedure has been satisfactorily used at Baltimore, Md., replacing the ferrous sulfate and lime treatment.

## Color Removal

Color in water is not objectionable to the average consumer unless greater than 20 ppm. It is obtained from soluble humic acids, tannins, and other related compounds.

These substances are in the colloidal state carrying negative charges and are removed by flocculation which occurs best at pH values below 4.6 or between 6.9 and 8.3. At the low value a reaction occurs between the negative color ion and the positive metallic ion of the coagulant, usually alum or iron salts, forming a definite compound. At pH values above 6.0 the color particles are mechanically entrapped in the floc.

Alum is used as a coagulant for many colored waters. The use of ferric salts as coagulants for these waters is increasing as they will produce floc in acid or alkaline waters. The compound obtained with iron coagulation has the formula of $Fe_2O_3 \cdot 2SiO_2 \cdot 3H_2O \cdot 4R$, when R indicates organic constituents. The Elizabeth City, N. C. plant has pioneered in this field, developing the procedures stated above. Coagulation followed by 4 to 6 hours sedimentation and then sand filtration, comparable to the procedure for turbidity removal, are the procedures involved.

Color may also be removed by bleaching with sulfur dioxide, as is done at Tampa, Fla., with excess chlorine or chlorine dioxide. These substances are very effective, provided the color is from tannin or other vegetable compounds and when sufficient contact time or aeration is utilized to rid the water of the excess gas prior to use.

## Corrective Treatment

Soft waters containing dissolved oxygen and carbon dioxide will excessively corrode iron and steel. The fundamental reactions underlying cold water corrosion disclose that iron dissolves in water producing atomic hydrogen with sufficient speed to keep a film of it at the surface of the metal. The rate of corrosion is in proportion to the loss of the protective hydrogen film by reaction with the dissolved oxygen in the water. It is apparent therefore that dissolved oxygen is the primary cause of pipe corrosion. Systems showing a continued decrease in oxygen content are corroding in direct proportion to this loss. With bright or clean iron surfaces, water at pH values between 5.0 and 9.0 corrode at equal rates.

The rust precipitated on pipe from waters containing free carbon dioxide is porous and does not retard the diffusion of the dissolved oxygen to the metal. When it is possible to precipitate rust in alkaline water, corrosion will be checked. The dense compact coating of rust and calcium carbonate precipitated when the water has a pH value greater than the calcium carbonate saturation point, serves as a barrier to the diffusion of the dissolved oxygen to the metal surface.

Carbon dioxide is removed by absorption in lime or other alkali. Sufficient alkalinity must be constantly maintained to neutralize the free carbon dioxide and keep the water at the calcium carbonate saturation point. Figure 44. Deposition of rust in alkaline waters is an indirect but effective method of protection. The practical value of this treatment is

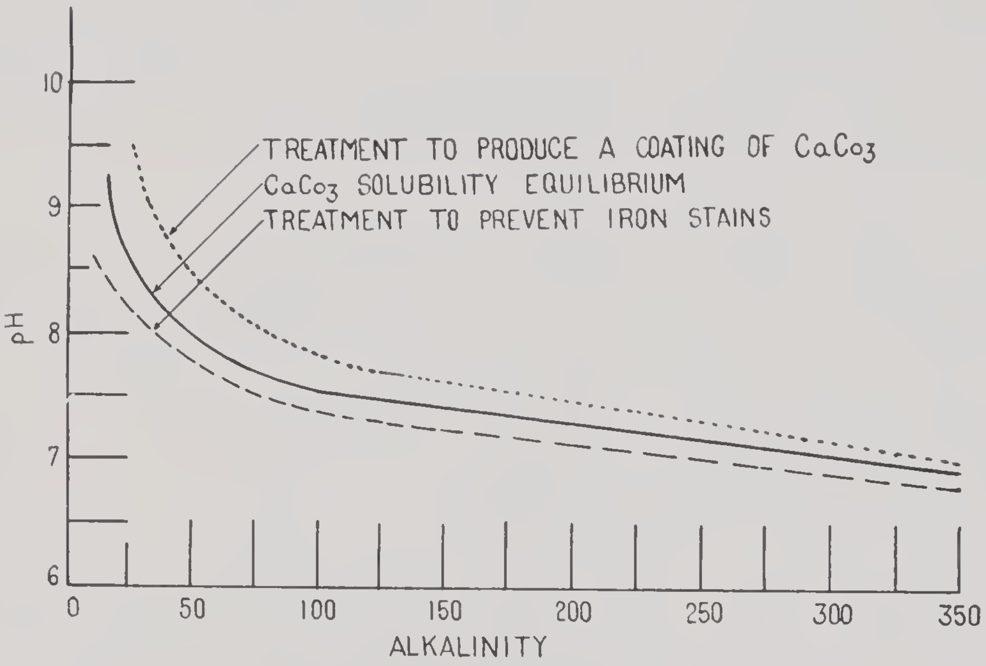



Fig. 44. Baylis calcium carbonate curve

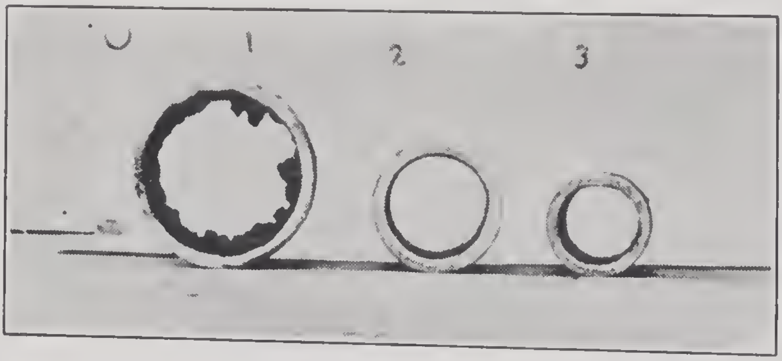


Fig. 45. Pipe taken from distribution system

shown in Figure 45, in which a pipe protected by lime treatment is compared with one not so treated.

## Softening

Hard water may be defined as a water requiring an excessive amount of soap to form lather. It is caused by the presence of calcium and magnesium salts which form insoluble compounds with soap without the production of lather. If these substances do not produce a taste, a hardness of 100 ppm. is acceptable for domestic use. A drinking water containing

300 ppm. of calcium bicarbonate, 1,500 ppm. of chloride or 2,000 ppm. of sulfate is unhealthful for most persons, causing gastric disturbances. These salts, particularly the sulfate, cause incrustation in kitchen utensils, house heating systems, industrial steam generating plants and also directly affect the manufacture of certain foods, textile dyeing, and other chemical industries.

A hardness of 100 ppm., expressed as calcium carbonate, is considered to be sufficiently soft for general domestic use and has been accepted as the criterion for municipal softening. The distribution of hard water in the United States covers a wide geographical area.

### *Lime-soda Process*

Softening of municipal water supplies is commonly accomplished by the lime-soda process as shown by the following reactions:

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O \qquad \text{(Lime)}$$
$$Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow Mg(OH)_2 + 2CaCO_3 + 2H_2O \qquad \text{(Lime)}$$
$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4 \qquad \text{(Soda)}$$
$$MgSO_4 + Ca(OH)_2 + Na_2CO_3 \rightarrow Mg(OH)_2 + CaCO_3 + Na_2SO_4 \qquad \text{(Soda)}$$

These reactions can be carried on simultaneously in waters containing both bicarbonates and sulfates by the addition of the lime and soda at the same time. The calcium carbonate formed will precipitate out leaving a residual hardness of 75 to 100 ppm.

Softening is accomplished by several stages. Coagulants are added to raw water. After mixing and settling, the softening chemicals are then introduced, given a secondary mixing and sedimentation; the effluent from this treatment is then carbonated with carbon dioxide to reduce the alkalinity to the calcium carbonate saturation point before filtration through sand beds. Recarbonation is necessary to prevent precipitation of the particles of dissolved unstable carbonates on the sand grains.

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca(HCO_3)_2 \qquad \text{(recarbonation)}$$

Mixing periods from 20 to 30 minutes with 3 to 4 hours for the primary sedimentation and 6 hours for the secondary are satisfactory. To convert the magnesium salts to the hydroxide, it is necessary to precipitate at pH values approximating 10.0 when using an excess of lime. Neutralization and precipitation of the excess lime with free carbon dioxide is practiced before filtration to avoid incrustation of the sand grains. A more palatable water is obtained with decided reduction in scale formation by this softening.

The chemicals may be applied in solution or with dry feed machines, and mixing is accomplished with either baffled basins or mechanical devices. Sedimentation may be obtained in the conventional basin or by the use

of sludge blanket devices. These units give complete softening with 45 to 60 minutes detention. A special adaptation of the sludge blanket is found in several patented processes. These softeners are effective with only 10 minutes detention, making them valuable for small installations.

Filter beds used in softening are of construction similar to those for general use, and the flow through them is at the rate of 2 gallons per square foot per minute. Carbon dioxide is obtained by burning coke, oil,

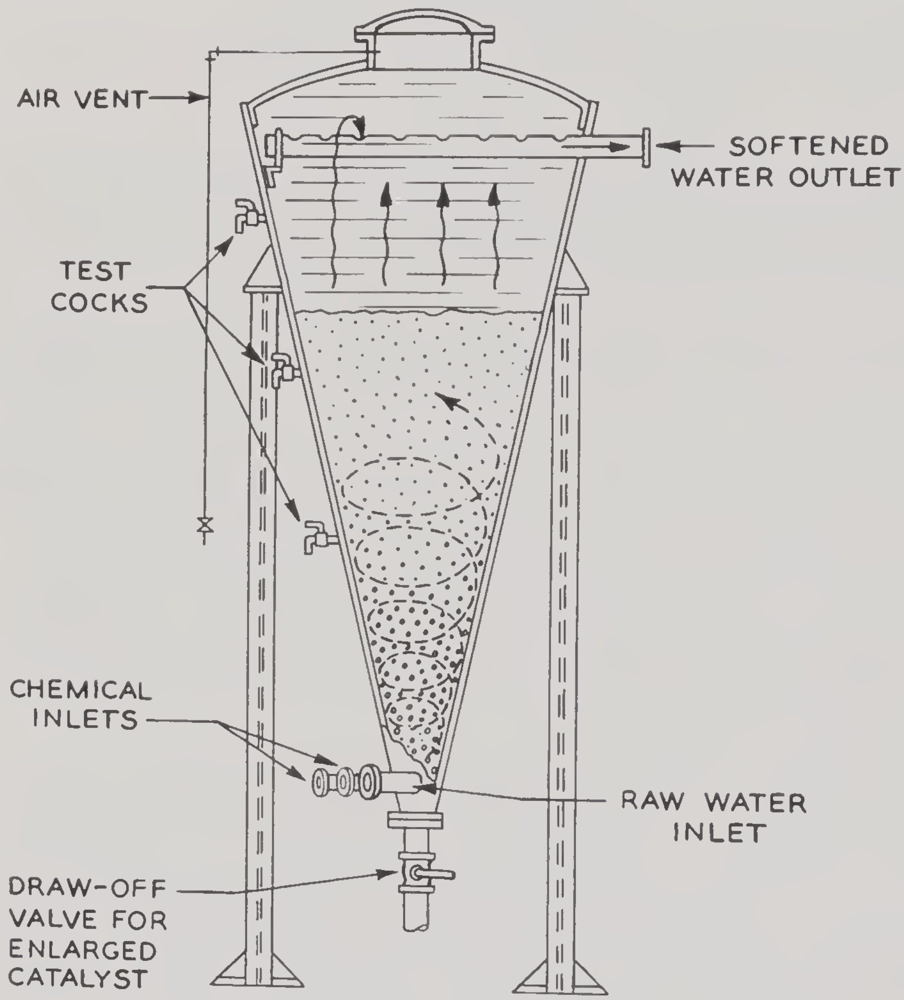



FIG. 46. The Spiractor. (Courtesy, The Permutit Co.)

or gas in a special furnace equipped with a scrubber to remove undesirable products of combustion. Commercially manufactured gas loaded in cylinders is also used.

The outstanding lime-soda ash treatment plant is at Columbus, O. In this plant the steps previously enumerated are carried out. The Chain of Rocks plant at St. Louis, Mo., is the largest municipal water softening plant in the world.

## *Use of Polyphosphates*

Normal carbonates may be retained in solution by the use of sodium hexametaphosphate. A dose of 1 to 2 ppm. applied after softening will

prevent the precipitation of calcium carbonate on the filter sand and stabilize the alkalinity throughout the distribution system even at high pH values above 10.0. Prevention of "red water" at these high alkalinities has been satisfactory with this treatment, since the hexametaphosphate does not reduce the pH value of the filtered water. The ions of calcium, magnesium, iron, manganese, etc. are held in solution or sequestered.

### *Zeolite Softeners*

Softening of water by the use of zeolite minerals is another popular method. These compounds are found as natural "green sands", or they are manufactured. They are basically sodium aluminum silicates having the general formula of $3SiO_2 \cdot Al_2O_3 \cdot Na_2O$. These silicates have the property of base exchange; that is, they will give up their sodium content in exchange for the calcium or magnesium ions in the water. When the sodium ion in the mineral has become exhausted, it is regenerated by passing a strong solution of sodium chloride (brine) through it, reversing the reactions and restoring its base exchange capacity. Upon completion of the reaction the excess brine is washed from the bed and the softener is ready for use.

Zeolite filters are commonly used with industrial water supplies and are constructed similarly to pressure filters with the zeolite replacing the sand. They are effective with *clear* water since turbidity particles will clog the pores of the mineral with loss of base exchange capacity. Flow through these beds may be downward or upward depending on the plant conditions. They are operated at rates varying from 4 to 6 gallons per square foot per minute.

These units have been installed in a few municipal plants. Zeolite plants are economical when there is no place for sludge disposal from the lime-soda ash process, and in small plants the simplicity and ease of manipulation make the process desirable. All hardness can be removed but the usual practice is to soften part of a municipal supply and dilute it with unsoftened water so that the resultant water as delivered has a hardness of about 100 ppm.

## Disinfection

Of all the many substances possessing germicidal properties only chlorine, ozone, ultra violet radiation, and oligodynamic silver are of practical value in water purification. Of these chlorine is extensively utilized and ozone to a limited extent. See Page 13.

The factor of cost, together with convenience of operation and absolute dependability when applied under plant conditions, will determine the selection of a germicide. Ozone and ultraviolet radiation are effective reagents when used under favorable conditions but the complicated control

procedure and cost of application frequently prohibit their use for water treatment. The low cost of chlorine together with simplicity and reliability of service has made it the germicide of choice in most instances.

*Chlorine*

Chlorination of water prior to filtration, commonly known as prechlorination is usual practice. It is an excellent safeguard against sudden pollution in the raw water and also provides a greater margin of safety by reducing any excessive bacterial load in all phases of the purification process.

By far the major portion of chlorine added to water for disinfection reacts with and is consumed by the organic material in the water. It is therefore necessary to satisfy the requirement of reducing compounds before any excess or residual chlorine can exist. This capacity of water to reduce chlorine is measured as its "chlorine demand" and, before complete disinfection may occur, all of this demand must be satisfied. This demand is defined as the amount of chlorine consumed after a contact period of 30 minutes.

**Testing for Residual Chlorine.** The ortho-tolidine test used for many years is based on a general reaction not specific for chlorine. It is affected by unstable oxides, and reducing compounds give false readings. The color produced in the test may therefore be produced by free chlorine, combined chlorine, interfering oxidation, or reduction compounds. With the development of differential tests it is now possible to determine the concentration of these substances and evaluate them separately.

The more or less regular appearances of coliform organisms and high bacterial counts in a distribution system formerly thought to be caused by resistant or attenuated strains, were actually due to insufficient chlorine to kill them. This early error can be explained by the fact that frequently when chlorination is controlled by the conventional ortho-tolidine test, the available free chlorine actually present is much less than that indicated by the color of the test. Interfering substances may give a fictitious test for the presence of free chlorine. The presence of chlorine in combination, therefore not effective as a bactericide, is also shown by the ortho-tolidine test.

The sodium arsenite modification of the ortho-tolidine test as developed by Hallinan in 1944 makes it possible to measure the concentration of free available chlorine, chloramine, and interfering substances. When used as a control for the "flash" test proposed by Laux it has made accurate chlorination possible.[7,15]

Using a prechlorination dosage of sufficient concentration to give a free available residual of 0.3 ppm. in the plant effluent has practically

eliminated coliform organisms from the Baltimore, Md. distribution system. Only sporadic outbreaks of *B. coli* have occurred which investigation indicated were caused by repair or construction work of magnitude in localized areas of the distribution system. This treatment has been accomp-

Fig. 47. Residual chlorine recorder. (Courtesy, Wallace and Tiernan Co.)

lished without taste complaints. Plant control is based on the "flash" test with daily laboratory checks by the ortho-tolidine-arsenite test. This method of determining the free available residual chlorine is now in common use.

*Chloramines*

The delayed action of chloramines at varying pH values is of advantage in maintaining a distribution system free from bacteria. Their use is

desirable when it is not possible to carry a free available residual chlorine concentration of not less than 0.2 ppm. throughout a system. Inability to maintain a 0.2 ppm. residual may be caused by the dissipation of free chlorine in the water of open reservoirs or by the formation of objectionable taste-producing chloro-phenols. A ratio of 4 parts of chlorine to 1 part of ammonia as applied at the treatment plant is needed for the formation of chloramines.

The experience at Houston, Texas, of using a prechlorination dose of 5 ppm. of free available residual chlorine for disinfection with post chlor-

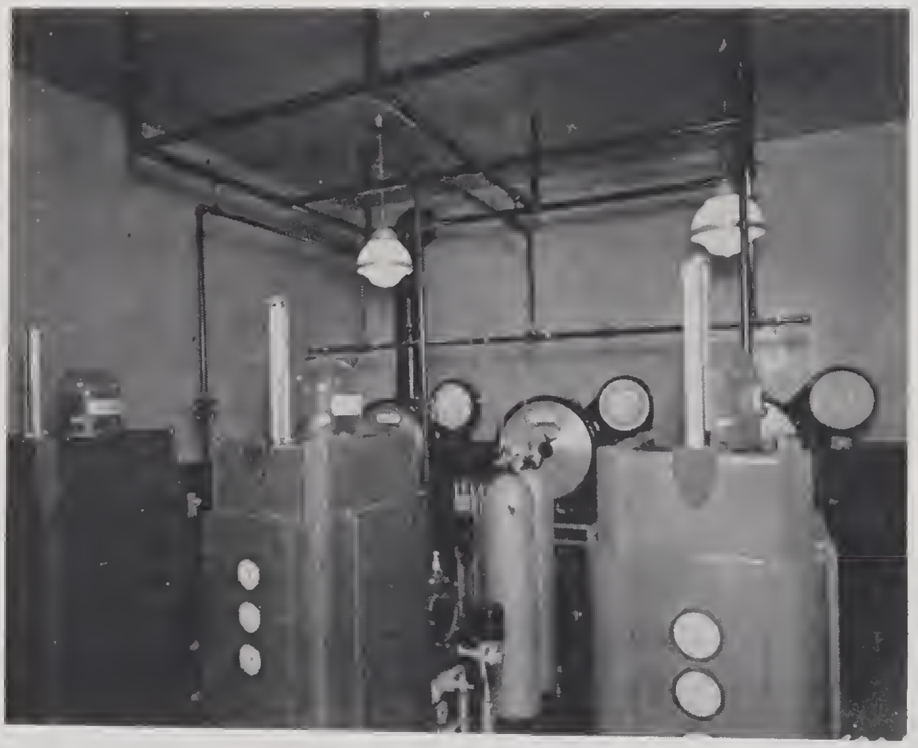


FIG. 48. Battery of chlorinators serving an automatic station, Baltimore, Md.

amine treatment to carry 1.0 ppm. residual in the "clear well" is typical. After 60 days 0.1 to 0.3 ppm. chloramine was found in all "dead" ends of the distribution system.

*Chlorination of Secondary Reservoirs*

Many distribution systems have uncovered secondary reservoirs introduced into them to maintain adequate pressure and reserve supply. These open reservoirs are exposed to contamination by air-borne dirt, bird excreta, and debris. To overcome this pollution and to assure the absence of coliform organisms secondary chlorination is practiced. It cannot be considered a good substitute for sanitary control.

The daily application of high test hypochlorites to the water surface is common practice. These are applied either by spraying a solution over

the surface or distributing the powdered material from a boat. Accurate dosage is difficult to obtain and bacterial control is erratic.

To assure adequate disinfection, automatic chlorination of the flow from secondary reservoirs as it discharges into the distribution system is practiced. This is done at the five equalizing reservoirs at Baltimore, Md., and at the four in New York City.[12] Many other cities have similar secondary reservoirs, some of them covered.

### *Disinfection Control at the Treatment Plant*

Disinfection control, in the final analysis, depends upon the absence of organisms of the coliform group. Regular systematic bacteriological analysis of a treated water is the best assurance of its purity. It is not safe to attempt to control a plant on the basis of a single sample per day, and when samples are taken weekly serious hazards may result. Samples must be collected at the plant at least twice daily, when the plant is in continuous operation, preferably every 8 hours. Plants handling large volumes of water or raw water subject to wide variations in quality, should have more frequent samples taken. When a plant is intermittently operated, two samples daily, at properly spaced intervals, should be collected. Additional samples must always be taken from the distribution system.

## Cross Connections

Direct cross connection between a water system carrying potable water and one of doubtful purity should not be permitted. Industrial, institutional, and domestic supplies of questionable purity are occasionally inter-connected to a public system. Drainage and waste pipes from plumbing systems are found connected to flushing lines from the distribution system. Sewage may enter such a system by back siphonage under conditions of partial vacuum resulting from faulty plumbing fixtures. This partial vacuum can be created in a water system by a heavy demand caused by large fires or a break in the mains. A heavy demand in the lower floors of a multi-floor building can appreciably reduce the pressure and produce a partial vacuum in the system in the higher floors.

Some states and many cities prohibit cross connections. Others permit them under controlled conditions. These regulations include the use of double check valves with "bleeders" between the dual supplies. The introduction of potable water into non-potable systems should be done by means of overhead outlet pipes that feed into a tank in the non-potable system. An air gap should separate the outlet pipe and the highest possible surface of water in the tank. When dual supplies are present in a building, the pipes of each should be painted a distinctive color. Direct connection of a water line to sewers for flushing purposes is usually prohibited. The

direct discharge of cooling water from a potable system to a sewer, without an air gap, is not permitted. Such a prohibited connection has been found in cooling water systems used in air conditioning and industrial apparatus.

Back siphonage connections such as submerged water inlets into wash tubs, slop sinks, hospital equipment, industrial process tanks, and improperly constructed flush toilet valves are cross connections frequently discovered. Whenever the water outlet is below the elevation to which the water in the recepticle can rise, the connection is classified as a submerged inlet. Many of these installations can be made safe by changing the submerged inlet to an overhead line, with an air gap, above the top of the tank or tub. Vacuum breakers or backflow preventers are now installed on flush toilet valves and similar devices. They are designed to immediately admit sufficient air, should a negative pressure occur, into the piping to cause the water in the riser pipe to drop below the elevation of the vacuum breaker. This entrance of air into the system breaks the column of water and prevents siphonage of fluid from the plumbing fixtures. There are various types of vacuum breakers in service.

An amoebic dysentery epidemic of magnitude caused by pollution from cross connections occurred in Chicago in 1933. It centered in two hotels of that city which received water from the public supply. One hotel was indirectly supplied from the other. In one hotel the city water was cooled by refrigerating coils in an open water tank. The coils were cross connected between two pipes carrying the condenser discharge, and a house sewer hung on the basement ceiling of the hotel. A second hazard was revealed in that the circulating drinking water tank was so located that the 6 inch sewer line passed directly over it. At a point over the circulating water tank a hole had developed in the sewer pipe. It had been closed with a wooden plug which had rotted to such a degree that sewage dripped into the tank. The resulting contamination of the circulating tank was the principal cause of infection among the hotel guests. During this period the sewers were overloaded because of the influx of patrons to the Century of Progress Exposition. Additional sporadic instances of overloading of the sewer lines were created by local rainstorms of high intensity.

## Addition of Fluorides

The application of sodium fluoride to drinking waters is believed to minimize the incidence of dental caries. This theory is based upon observations among people drinking water that naturally contains fluorides. Experimental treatment of the water furnished by the public supplies of Newburgh, N. Y., Grand Rapids, Mich., and Brantford, Ont. began in 1945. This is a 10 year program including medical and dental examinations of the inhabitants and other adequate control groups. Its practical eco-

nomic value is yet to be determined. However, results so far indicate that the addition of fluorine to drinking water will effect a marked reduction in dental decay if 1.0 ppm. content is maintained.

## Standards of Quality

A potable water as defined by the revised United States Public Health Service Standards[25] has the following characteristics:

*Physical properties.* The turbidity shall not exceed 10 ppm., color 10 ppm., total solids, 1,000 ppm. and odor and taste shall be absent.

*Chemical properties.* Lead shall not exceed 0.1 ppm., copper 3.0 ppm., zinc 15.0 ppm., magnesium 125 ppm., iron 0.3 ppm., and sulfates be limited to 250 ppm. with chlorides set at 250 ppm. or just below a saline taste concentration.

*Bacterial properties.* The bacteriological examination . . . shall be of samples collected at representative points throughout the distribution system. The frequency of sampling and the location of sampling points on the distribution system shall be such that will determine properly the bacteriological quality of the water supply. The minimum number of samples to be collected from the distribution system and examined . . . each month shall be in accordance with . . . the relationship of population served:

| Population served | Minimum number of samples per month |
|---|---|
| 2,500 and under | 1 |
| 10,000 | 7 |
| 25,000 | 25 |
| 100,000 | 100 |
| 1,000,000 | 300 |
| 2,000,000 | 390 |
| 5,000,000 | 500 |

Of the standard 10 cc. portions examined in accordance with the standard procedure, not more than 10 percent shall show the presence of organisms of the coliform group. Occasionally 5 percent of the standard samples may show the presence of the coliform group when 20 or more samples have been tested, but if less than 20 samples have been examined only one standard sample may contain this group of organisms. Any series of samples must conform to both requirements.

These standards limit the monthly density of coliform organisms to 1 per 100 cc. of water tested. Should this concentration be frequently exceeded, the second part of the standard condemns the supply as a potential health hazard. An occasional increase in coliform density is permitted, in recognition of the fact that water supplies do actually vary from day to day.

It is significant that in the Standards emphasis is placed upon excellent sanitary control rather than upon direct bacteriological testing. While the importance of bacteriological control is recognized, the Standards properly interpret the results of these tests only as indicating irregularities and pollution dangers, rather than establishing pollution. Therefore every effort should be made to deliver sterile water to the consumer rather than a product that just meets the minimum standards.

The chemical and physical factors established by the Standards obviously assure a palatable water. A noticeably colored or turbid water or one with an unpleasant taste is looked upon with suspicion by the public. The physiological effect of the dissolved chemical constituents upon persons is difficult to evaluate. The effect of high concentrations of magnesium sulfate is well recognized and poisonous metals such as lead and copper cannot be permitted in quantity. Where chemical purification is practiced, excess chemicals should be avoided. Every effort should be made to promote as satisfactory a water as possible in relation to its inherent chemical constituents, with due regard to the natural characteristics of the region from which the supply is obtained.

Responsibility for the safety of a water supply is vested in the various state departments of health and control procedures are administrated by the state sanitary engineer. Review of the design and certification of the plans by this official, prior to construction, assure the satisfactory installation of a waterworks system. Frequent inspections and surveys of the operational features keep the system free from defects.

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## Chapter VII

# DISPOSAL OF SEWAGE

One of the disadvantages of modern civilization lies in the fact that many of the advantages we enjoy today carry with them inconveniences or even hazards not present in earlier times. The problem of sewage disposal has become more acute as people have concentrated geographically to obtain the benefits of city life. As cities have grown and spread, the once isolated creek or pool or ocean beach has become a center of activity and recreation. The quantities of sewage at one time small enough to make burial or dilution a feasible method of disposal, have increased to the point where the older methods are no longer practical.

The danger to public health of a polluted water supply has been previously discussed. Any hazards attributed to an unsafe water supply are equally true of improper sewage disposal, since the danger in drinking water originates from contamination by human excrement.

Several other grave dangers exist in improperly treated sewage. The ordinary house fly has a strong affinity for human feces, both as a breeding place and as a source of food. The incidence of typhoid fever during the Spanish-American War has been charged to flies. There is good evidence that infection of human food resulted from access to the food by fecally contaminated flies. One observer was intrigued by the white-legged flies crawling over his food. Closer examination showed the white legs came from deposits of lime. It was not difficult to trace the lime to the source of supply—the lime sprinkled feces in an open privy.

Hookworm disease is closely associated with undesirable methods of human waste disposal. Hookworm larvae in the feces-polluted soil get on human susceptibles and enter the skin to produce new cases of infestation. The significance of the poliomyelitis virus in sewage is still undetermined.

## BASIS OF SEWAGE TREATMENT

The most important objects of sewage treatment are:

1. Protection of water supplies, private or public, obtained from surface or underground sources.
2. Protection of human food to be eaten raw.
3. Prevention of the creation of public health hazards in recreational areas.
4. Protection of waters to be used for industrial purposes.
5. Protection of fish and other aquatic life.
6. Prevention of pollution of shell-fish.

7. Prevention of hazards to livestock.
8. Prevention of pollution of waters used for natural ice.
9. Prevention of conditions objectionable to sight and smell.
10. Protection of soil against pollution.

The extent to which sewage should be treated will depend upon its strength and quantity; the amount of pollution already in the water into which the treatment plant effluent is discharged; the volume and variation of flow, particularly during dry periods of the year, of this diluting water; and the use made of the diluting water below the sewage works.

## URBAN DISPOSAL PROCEDURES

For many centuries drainage systems have been a necessary adjunct to municipal life. Excavations made by archeologists in Crete, Greece, and Mesopotamia have indicated that house drains and sewers were used to carry off the drainage from dwellings and buildings. The Cloaca Maxima, a large underground conduit in Rome, is one of the outstanding examples of a drain sewer used more than 2,000 years ago. Sewers have been in service for many centuries in the older European cities, notably London and Paris.

A study of sewerage facilities conducted by the United States Public Health Service furnishes good evidence of the extension of sewage disposal facilities in the United States. In 1860 1 person out of 30 was served by a sewer system: in 1945, this figure was 1 out of 2. Between 1930 and 1945 more than 3800 communities installed sewer systems. By 1945 approximately 75,000,000 people in the United States disposed of their wastes through sewerage systems. The sewage of about one third of this population is not treated before discharge into the receiving waters. Practically all communities of 10,000 or more population had sewerage systems in 1945, and about 91 per cent of the communities with populations between 5000 and 10,000 had them. Less than 18 per cent of the communities below 1000 population had such systems.[15]

Today adequate sewerage facilities are being demanded more than ever before. Cesspools and privies are becoming a thing of the past in many parts of the country. A great many small towns with no more than a few thousand people are now provided with sewerage systems, which in many cases include sewage-treatment works.

### Lawrence Experiment Station

The gross pollution of streams in the eastern portion of Massachusetts had become such a serious problem that in 1881 and again in 1884 special committees were appointed[18] to consider a "general system of drainage" for the streams near Boston. Their reports recommended the establishment

of a permanent organization to control the pollution of the streams in this state. In accordance with these recommendations the Legislature in 1886 charged the State Board of Health with the duty of advising its citizens as individuals and also as civic units as to the proper methods of water supply and sewage disposal. The Board was also ordered to collect information and to conduct experiments on the purification of sewage.

This agency in 1887 established the Lawrence Experiment Station on the banks of the Merrimac River under the direction of Allen Hazen. Sewage purification as a function of the slow oxidation of organic matter carried on by living bacteria and micro-organisms, was the fundamental fact developed at this Station. Upon this general principle depends the functioning of the contact bed, the sprinkling filter, and the activated sludge process. The principles established at this station, excluding chemical precipitation, underlie many modern sewage disposal processes.

The earliest investigations that had any close relationship to our present disposal methods were carried on in Berlin by Dr. Alexander Mueller. During the years 1865 to 1870, he studied the effects of filtering and concluded that the stabilization of the sewage passing through filters was produced by living organisms in the filters. These conclusions were verified by two Frenchmen, Muntz and Schoesing, in 1877. The discovery of the typhoid organism in 1880 by the German, Eberth, helped toward the understanding of the sewage-water-human triangle of typhoid fever. The first work of significance in the United States was carried on at the Lawrence Experiment Station in Massachusetts.

## Types of Sewerage Systems

There are two types of sewerage systems; separate and combined. In many instances both are found in the same city.

**Separate Sewerage Systems.** Separate sewerage systems are so-called because a single system is used to carry off "sanitary" wastes and another is utilized for drainage of storm waters. The sanitary sewer carries off the drainage from kitchens, washrooms, bathrooms and toilets, together with the wastes from manufacturing and industrial plants. This system should exclude all roof, ground, and surface drainage. A separate system of sewers, called storm drains, is provided for surface drainage. The storm drains discharge into a convenient water course while the sanitary sewers often terminate at a sewage-treatment works.

**Combined Sewerage Systems.** In a combined system the sewage from all dwellings and buildings together with the storm flow from the streets and other areas discharges into a single system of sewers. If the sewage is treated at a sewage treatment plant, it is usually necessary to turn the entire increased flow directly into the receiving bodies of water after

heavy rain or times of high storm water flows. This is known as the "disposal of storm water wastes".

With the use of a combined system the disposal of storm water run-off requires extra pumps, larger interceptor and outfall sewers, and greater facilities at the treatment works with consequent increased construction and operating costs. Only the unusual storm should be considered as of sufficient intensity to justify by-passing the sewage around the treatment plant even when the discharge of the sewer goes into a large body of water. It should be assumed, however, that by-passing will occur whenever sewage flows are increased markedly. Over a period of years the separate system is more economical than the combined, particularly when treatment works are included.

## Composition of Sewage

Urban sewage is the liquid wastes of a community containing domestic sewage, industrial wastes, ground water and, in combined systems, surface or storm water.[14]

Keefer[11] has shown that:

> "Municipal sewage contains mineral, animal, and vegetable matter in suspension and solution together with a large number of bacteria. The materials in suspension consist of paper, pieces of food, grease, fecal matter, match sticks, etc. Fresh sewage has a musty odor, which is not especially offensive. However, within a few hours decomposition begins and objectionable odors are produced. The concentration of suspended and dissolved materials in sewage is usually quite small, amounting to less than 1 percent. About one-half of this material is of mineral origin and is inoffensive."

The suspended solids in sewage consist of finely divided materials from kitchens, toilets and bathrooms, street washings and industrial wastes. The substances in solution consist of all the chemicals originally in the water plus all those added through the sewage. Water-borne industrial wastes may be defined as the liquids and solids discharged into the sewer from manufacturing establishments. These wastes are often much stronger than domestic sewage since they contain a greater concentration of unstable organic matter. They may therefore require more extensive treatment for purification.

Sewage is considered to be fresh when of comparatively recent origin; stale, after having stood for some hours, with increased bacterial activity and reduced oxygen content; and septic, when all the dissolved oxygen has been used up with resultant putrefactive conditions.

The chemical and physical characteristics of sewage vary widely at different places and depend upon the water consumption, the domestic habits of the people, and the amount and kind of industrial wastes discharged into the sewers.

The B.O.D. (biochemical oxygen demand) of sewage is used as a measurement of its strength. It is the quantity of oxygen required in a given time and at a given temperature to satisfy the combined biological and chemical oxidation demands of the sewage. In natural decomposition the oxygen is obtained from the breakdown of chemical compounds dissolved in the sewage, from the oxygen dissolved in it, and from plant respiration. The standard incubation period for the laboratory determination of B.O.D. is 5 days at 20° C. The results of this determination show 68 percent of the total ultimate oxygen demand. To date it is the best test that has been developed for determining the strength of sewage. The suspended solids are those components of sewage that settle out of the liquid. They are the basis for calculating the velocity needed in pipes to prevent silting; the amount of sludge to be removed; and the size of the various parts of the treatment works.

## Principles of Treatment

Sewage treatment works are classified as either primary or complete treatment units depending upon the degree of purification given. Fine screening and plain sedimentation tanks provide primary treatment while trickling filters, bio-filters, and activated sludge plants give complete treatment. Primary treatment removes the suspended matter. Complete treatment removes the suspended particles, and colloidal and dissolved matter in addition. The extent of treatment is usually measured by the B.O.D. and suspended solids removed.

The final method of treatment is based upon the circumstances peculiar to each situation. If treated sewage is to be discharged into a small water course a high degree of treatment is necessary. On the other hand, if the effluent from the treatment plant is to discharged into a large body of moving water in such a location that water supplies, bathing beaches, and shell-fish areas are not endangered, a less thorough method of treatment can be used.

Treatment may consist of one of several different operations or it may include two or more in any sort of combination. The general operations possible are:

- Dilution
- Screening
- Sedimentation
- Biological treatment
  - a. Treatment in sand or gravel beds.
  - b. Introduction of air or oxygen in presence of activated solids.
  - c. Anaerobic decomposition of solid matter in storage tanks.
- Chemical precipitation
- Application to land
- Disinfection with chlorine

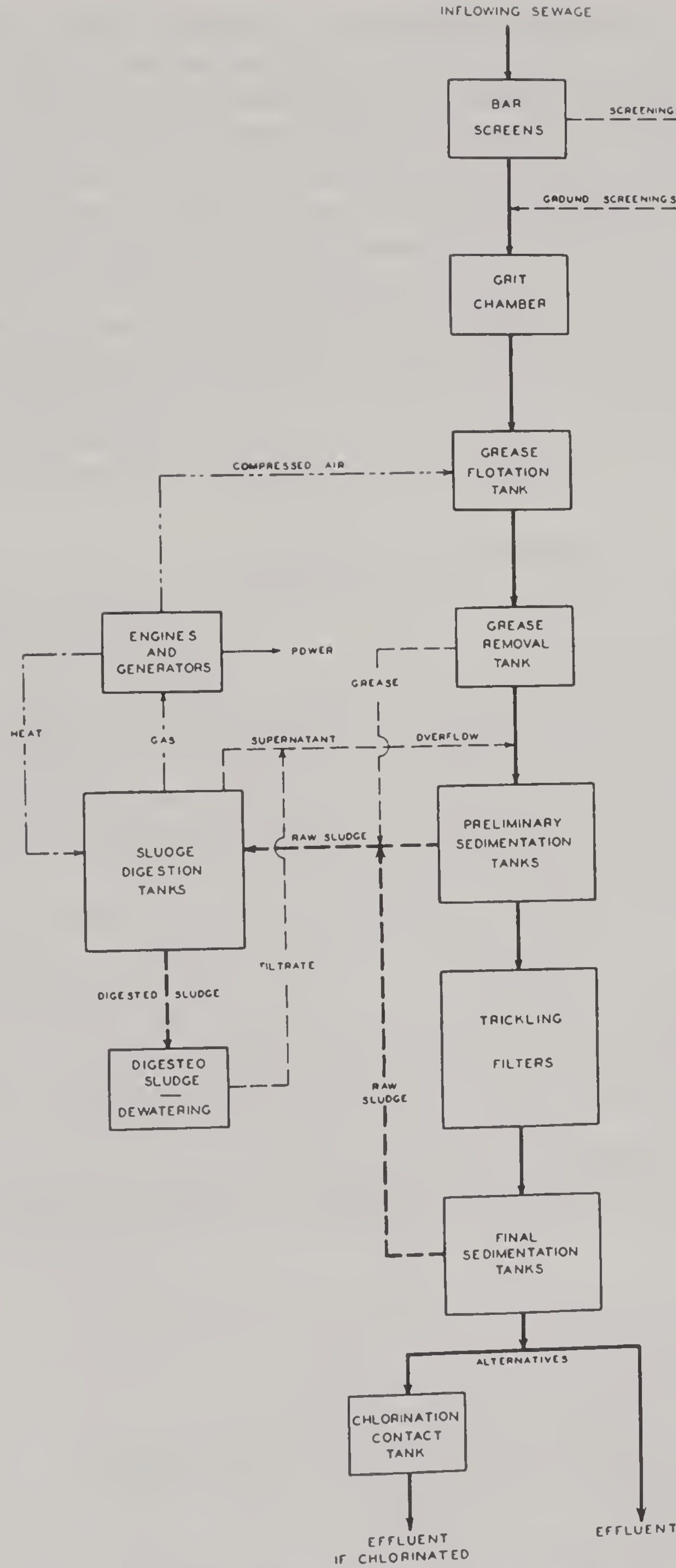


FIG. 49. Diagram typical sewage treatment works

Combinations of some of these steps or operations in treatment are found in common types of treatment units. The Imhoff Tank combines both sedimentation and anaerobic stabilization or "digestion". The septic tank of the private home combines the same principles. The modern plant with complete treatment might include screening, sedimentation, digestion of the settled material in separate compartments, biological treatment through beds of crushed rock of the liquids drawn off the sedimentation tanks, and finally dilution. Prior to dilution, chlorine disinfection may be used. The methods used and their combination can be determined only through study by trained engineers of the peculiarities of the sewage, the reasons for treatment, the quality of effluent desired, and the economic limitations of a specific situation.

## Disposal by Dilution

The sewage from many communities is discharged into lakes, rivers, and other bodies of water without treatment. This is probably the oldest and still most widely used method of disposal. Certain physical, chemical and biological processes are responsible for the purification obtained by dilution. In addition, the mere act of dilution will eliminate many of the common objectionable characteristics of sewage.

Some of the heavier sewage solids settle out. Their concentration also becomes less as they disperse into the diluting water. The dissolved oxygen of the water is responsible for the stabilization of the organic materials by biochemical means. Many types of plant and animal life contribute to the purification process. Algae ingest simple chemical compounds, and give off oxygen, which prevents the formation of putrefactive conditions. A variety of aquatic animal life consumes organic substances and bacteria.

A sufficient supply of dissolved oxygen in the water at all times is essential to support fish life and to prevent nuisances. This requirement is especially true in summer, when water retains only from about 55 to 65 percent as much oxygen as in winter. Some authorities recommend that the amount of dissolved oxygen in the diluting water should not fall below 50 percent of saturation. Ordinarily when there is a flow of water from 5 to 7 cubic feet per second for each thousand persons served by the sewage system discharging into the water course, offensive conditions will not result. In case the sewage is treated prior to dilution, as in sedimentation tanks, considerably less diluting water is required. Conversely, if the body of water is already partially loaded with unstabilized sewage, it will be able to accommodate a proportionately smaller sewage load without the development of nuisances and public health hazards.

### *Conditions in New York Harbor*

Dilution after screening of sewage in the waters of New York harbor has been the normal method of sewage disposal for the communities

adjacent to the lower Hudson River. A series of discharge outlets is situated in the Hudson and East Rivers above Governors Island, in Kill van Kull, and in Upper Bay. This volume of waste is equivalent to about one-half of the dry weather run-off.[17] Pollution of the Hudson begins at Troy, N. Y., and continues to the mouth in New York harbor. The major pollution load is discharged in the lower 50 miles of the river from the urban New York and New Jersey populations and industries. With low river flow the dissolved oxygen concentration varies from 45 percent saturation below Albany, N. Y., to a high of 80 percent in the shallow Tappan Zee area, with subsequent severe reduction almost to depletion just above the Upper Bay. The contributing population is nearly 11 million, discharging about 1500 million gallons per day of sewage. About 70 percent of this sewage is from New York City. The Passaic Valley trunk sewer, serving 22 communities in New Jersey, was placed in service in 1924. This sewer discharges through multiple outlets, 25 feet deep, in the Upper Bay near Robbins Reef Light. Other sewage discharging into the harbor includes effluents from the South Yonkers screening plant, placed in service in 1930; the Perth Amboy (1935), and the Elizabeth Joint Meeting works (1936). These projects have corrected the obviously offensive conditions in the river but have increased the total pollutional load in the harbor.

To alleviate pollutional conditions that cannot be assimilated by these waters and adequately protect the large ocean beaches, an extensive sewage disposal program is in progress for New York City. Thirteen treatment works are now in operation treating 410 million gallons per day or 30 percent of the sewage discharged. They are listed in Table 12. When completed the program will comprise treatment for 1453 million gallons of sewage per day in 17 plants.

The sewage treatment plant building program in New York City is part of the overall improvement plan of the Interstate Sanitation Commission, a body composed of representatives from New Jersey, New York, and Connecticut, to eliminate pollution in greater New York harbor. The inner harbor water is now classified as being unfit for recreational uses. Treatment under present agreements must remove at least 10 percent of the suspended solids and the dissolved oxygen content of the receiving waters must not fall below 30 percent of saturation. The outer harbor water is classified as fit for recreation and shell-fish propagation. Treatment must remove 60 percent of the suspended solids and be capable of keeping the coliform density in these waters at or less than 1 per ml. in at least 50 per cent of the samples tested.[9]

### *Chicago Drainage Canal*

The Chicago Drainage Canal is another classical example of the use of dilution as a sewage disposal method. Prior to 1900 sewage from this city

was discharged into the Chicago River which flowed into Lake Michigan. In 1899 pumps and a canal were installed to pass this grossly polluted water into the Des Plaines River, flowing to the southwest. This system became inadequate, and a direct connection, known as the Chicago Drainage Canal, was made in 1900. The flow of the Canal was from the Chicago River to the Des Plaines River, thus reversing the flow of the Chicago River.

This new canal was designed to carry 10,000 cubic feet per second of flow. As shown by the map in Figure 50 the Des Plaines River discharges

TABLE 12

*Installed Sewage Treatment Plants at New York, N. Y. and Chicago, Ill.*

| Location | Initial Operation | Capacity M.G.D. | Type treatment |
|---|---|---|---|
| New York | | | |
| Wards Island | 1937 | 180 | Activated sludge |
| Tallmans Island | 1939 | 40 | Activated sludge |
| Coney Island | 1935 | 70 | Primary sedimentation—Chemical precipitation |
| Bowery Bay | 1939 | 40 | Activated sludge |
| City Island | 1942 | 1.5 | Primary sedimentation |
| Jamaica | 1903 | 65 | Activated sludge |
| Twenty Sixth Ward | 1897 | 60 | Primary sedimentation |
| Chicago | | | |
| Morton Grove | 1914 | 0.2 | Imhoff and trickling filter |
| Glenview | 1924 | 0.2 | Imhoff and trickling filter |
| Northbrook | 1925 | 0.2 | Imhoff and trickling filter |
| North Side | 1928 | 250 | Activated sludge |
| West Side | 1930 | 472 | Imhoff tanks |
| Calumet | 1935 | 136 | Activated sludge |
| Southwest | 1939 | 400 | Activated sludge |

into the Illinois River below Joliet, Ill. At Grafton, Ill., the Illinois River discharges into the Mississippi. A short distance below the mouth of the Illinois River the Mississippi River is used as a source of water supply for the city of St. Louis. The Canal was put into service on January 17, 1900. St. Louis instituted proceedings in the Supreme Court of the United States against the State of Illinois and the Sanitary District of Chicago to prohibit utilization of the canal for sewage purposes. The evidence submitted in the case proved most conclusively that if and when it is possible for excessive oxygen to be present in a river, self purification with complete oxidation of sewage will take place.

Several legal actions brought against Chicago for use of the Canal for sewage disposal and for diversion of Lake Michigan resulted in regulations outlining permissible use of the Canal and diversion of lake water to 1500

*cu. ft. sec.* which will provide adequate dilution of the sewage treatment plant effluents.[19] In conformity with these regulations sewage treatment plants have been built as shown in Table 12.

## Use of Screens

Screens are widely used as a preliminary step in the treatment of sewage. Screens can be grouped into two classifications, coarse and fine. Coarse


Fig. 50. Map of the Chicago Drainage Canal and Illinois River. ("Sewage Disposal", Kinnicut, Winslow and Pratt, 2nd ed., p. 46, John Wiley Sons, 1919.)

screens, or "racks" as they are called, have clear openings varying from about one-half to 3 inches. The function of racks is the removal of large floating objects such as rags, pieces of wood, and similar materials, to prevent clogging of pumps and pipe lines. Many kinds of coarse screens are in service. The simplest, which are cleaned by hand, consist of a series of parallel steel bars set in a sewage channel at an angle of from 30° to 60° from the horizontal. The sewage flows between the bars, which retain any large suspended material. The screenings are removed manually or by mechanical means and are deposited in buckets or similar containers for disposal.

Many types of mechanically-cleaned racks have been installed in the

United States. The usual mechanically-cleaned rack consists of parallel steel bars, which are cleaned by a rake. The rake is moved upward automatically by means of steel cables or endless chains, dragging the screenings along the upstream surface of the bars to the top of the screen where the debris is dumped into receptacles. Racks of this type are operated by electric motors and can be kept in either continuous or intermittent service by means of an electric timing device.

FIG. 51. Mechanically cleaned bar screens, Appleton, Wis. (Courtesy, Link-Belt Co.)

The quantity of material retained by racks varies from about 1 to 6 cubic feet per million gallons of sewage. Mechanically cleaned racks remove a greater quantity of material than those cleaned manually since the mechanical cleaner reaches to the bottom of the screens—not a consistent practice on the part of laborers cleaning the racks manually.

Fine screens are sometimes the only mechanical device used in the treatment given sewage, or they may be installed to reduce the load on subsequent treatment units. Many types of fine screens have been used in this country and Europe. Of the first installations in America one was at Reading, Pa., and the other at Brockton, Mass. Experience has indicated that the most serviceable material for these screens consists of thin bronze plates with long, narrow perforations, two inches long, varying in width from about $\frac{1}{32}$ to $\frac{1}{8}$ inch. Fine screens are usually shaped like a disk or

drum. As the screen, which is partially submerged in the sewage rotates, the entrapped screenings are raised out of the sewage and are wiped off by movable brushes into suitable containers.

In contrast to mechanically cleaned coarse screens, which may be cleaned intermittently, fine screens are cleaned continuously during operation. The quantity of material removed by fine screens depends upon the character of the sewage. The amount varies from about 10 to 30 cubic feet per million gallons of sewage.

## Comminutors and Shredders

Since screenings present difficulties in disposal, some plants use comminutors to chop up much of the material that would be retained on screens. Comminuted particles are removed and treated with the suspended solids. The comminutor is a slotted drum, motor driven, which rotates vertically in the incoming sewage channel. The drum carries small projections which, upon rotation, cut coarse material into small particles that pass through the slots with the rest of the sewage. These devices are used extensively at small plants. Shredders are used at large plants.

## Disposal of Screenings

Screenings are putrefactive and offensive. Rapid disposal is essential. Passage through comminutors or shredders is the most practical method of disposal. Other methods are:

Burial in separate pits or with refuse in a sanitary fill.

Dewatering and incinerating separately or with refuse.

Burial is the most common method used at small plants for the disposal of screenings. At least 2 feet of earth cover must be used. If a sanitary fill site is reasonably close to the treatment works, burial with refuse is good practice.

Limited quantities of wet screenings may be burned in refuse incinerators, provided the volume introduced does not smother the fire. At some treatment works screenings are dewatered by "cider" presses and then burned. Incineration may be in conjunction with the incineration of municipal refuse or garbage, or in a separate unit for the final disposal of sludge. Units may be built specifically for the burning of screenings.

## Grit Chambers

Grit chambers, also known as detritus tanks, are used in the preliminary treatment of sewage. They are usually small basins designed to reduce the velocity of the sewage flow sufficiently to permit the heavy suspended materials to settle. The normal flow is at a velocity of 1 foot per second,

with a detention period of 1 minute. Easily settleable suspended matter, such as sand, gravel, and ashes, which might clog pipe lines and be difficult to remove from the settling tanks, are caught in the grit chambers. These chambers are always provided in plants treating the sewage collected through a combined system of sewers.

Specially designed outlets or weirs are provided to maintain the desired velocity of not over 1 foot per second through a wide variation in volume of the sewage flow. At least two chambers are necessary so that one can be kept in service even though another may be inactive for cleaning or repair.

Grit chambers in small plants are cleaned by manual labor. When cleaning is necessary the chamber is by-passed in the sewage treatment and the collected grit is allowed to drain. The accumulated material is then shovelled out in wheel barrows or carts. Many large plants use mechanical cleaning. Under these conditions scrapers, moving continuously and at a slow rate of speed, carry the settled grit to a collection trough or sump. Mechanical means are used to collect the grit from the troughs or sumps and load it into cars or other suitable receptacles. If mechanical cleaning is used, the grit chamber does not necessarily have to be taken out of operation.

## Disposal of Grit

The quantity of grit generally varies from 2 to 3 cubic feet per million gallons. Grit frequently is not offensive and can be used for making roads and paths or for filling in low ground. If the grit contains an appreciable quantity of decomposable material, it should be buried.

## Hampton Tanks

Separation of the digesting sludge from the settling solids in a compartmented tank, so arranged that the sludge settled from the flow chamber through special openings into the digestion chamber beneath it, originated at the Lawrence Experiment Station. The first practical application of this principle was developed by Travis at Hampton, England, about 1908, and became known, curiously enough, not by the name of the inventor, but by the name of the town in which it was installed, namely the Hampton Tank. It is also called the Travis hydrolytic tank.

In the design of this tank one-sixth of the fresh sewage passes through the bottom or sludge compartment for the purpose of re-seeding the digesting sludge with bacteria from the fresh sewage and for washing away poisonous substances that might be produced during the anaerobic decomposition. The division into two compartments gave an opportunity for anaerobic bacterial action in a chamber separate from that of the sedimenta-

tion compartment. A feature of the sedimentation chamber was a series of parallel slats or plates hung in the chamber to serve as "contact colloiders" to precipitate the finely divided colloidal material in the sewage.

The tank performed satisfactorily but was supplanted by a better design in the Imhoff Tank.

## Imhoff Tanks

Imhoff tanks were invented by Karl Imhoff, who first used them in the Essen District in Germany in 1907. They are a combination of sedimentation chamber and digestion compartment. As indicated in Figure 52, an Imhoff tank consists of two chambers, one above the other. They may be circular, square, or rectangular, with depths between 15 and 35 feet. The sewage flows through the upper chamber at such a low velocity that the settleable solids fall to the bottom of the sedimentation chamber, then slide through the open slot at the bottom into the lower portion of the tank, called the digestion chamber. The average detention period of the sewage as it flows through the top chamber is about 2 hours.

The solids accumulate in the bottom chamber in the form of a liquid mass called sludge, which contains from about 85 to 95 percent of water by weight. About 60 percent of the dried solids are organic compounds. Newly deposited sludge is gray or light brown in color, and is said to be raw or undigested. The material then has an offensive odor. Under proper biochemical conditions the sludge decomposes within 30 or 40 days, and the organic compounds are reduced so that the amount in the dry solids varies from about 40 to 55 percent.

During the digestion process gases are produced, which rise in stacks or gas vents and escape into the atmosphere. At the same time some of the solids are frequently lifted by the gas and form a layer of scum at the surface. The tank is designed so that under normal operating conditions a deflector at the top of the sludge compartment prevents gas and scum from entering the settling chamber. In the operation of the tank, sludge should never be permitted to accumulate to such a depth that it gets above the deflector; otherwise it will enter the settling compartment and produce a poor effluent.

The digestion chamber should be large enough to store sludge during the winter when decomposition practically ceases and when weather conditions do not usually permit the withdrawal and drying of the sludge. The size of the digestion chamber depends largely upon the amount and the character of the solids removed from the sewage and also upon the temperature in the compartment.

The normal design is 3 cubic feet per capita. Sludge is removed under hydrostatic pressure through a draw off pipe and dewatered on sand beds.

As a greater percentage of solids settles near the inlet end of a tank, and as it is desirable to have the sludge distributed as uniformly as possible in all parts of the digestion chamber, rectangular Imhoff tanks are often designed so that the direction of flow can be reversed. Under these conditions the outlets of the tank become the inlets, and vice versa.

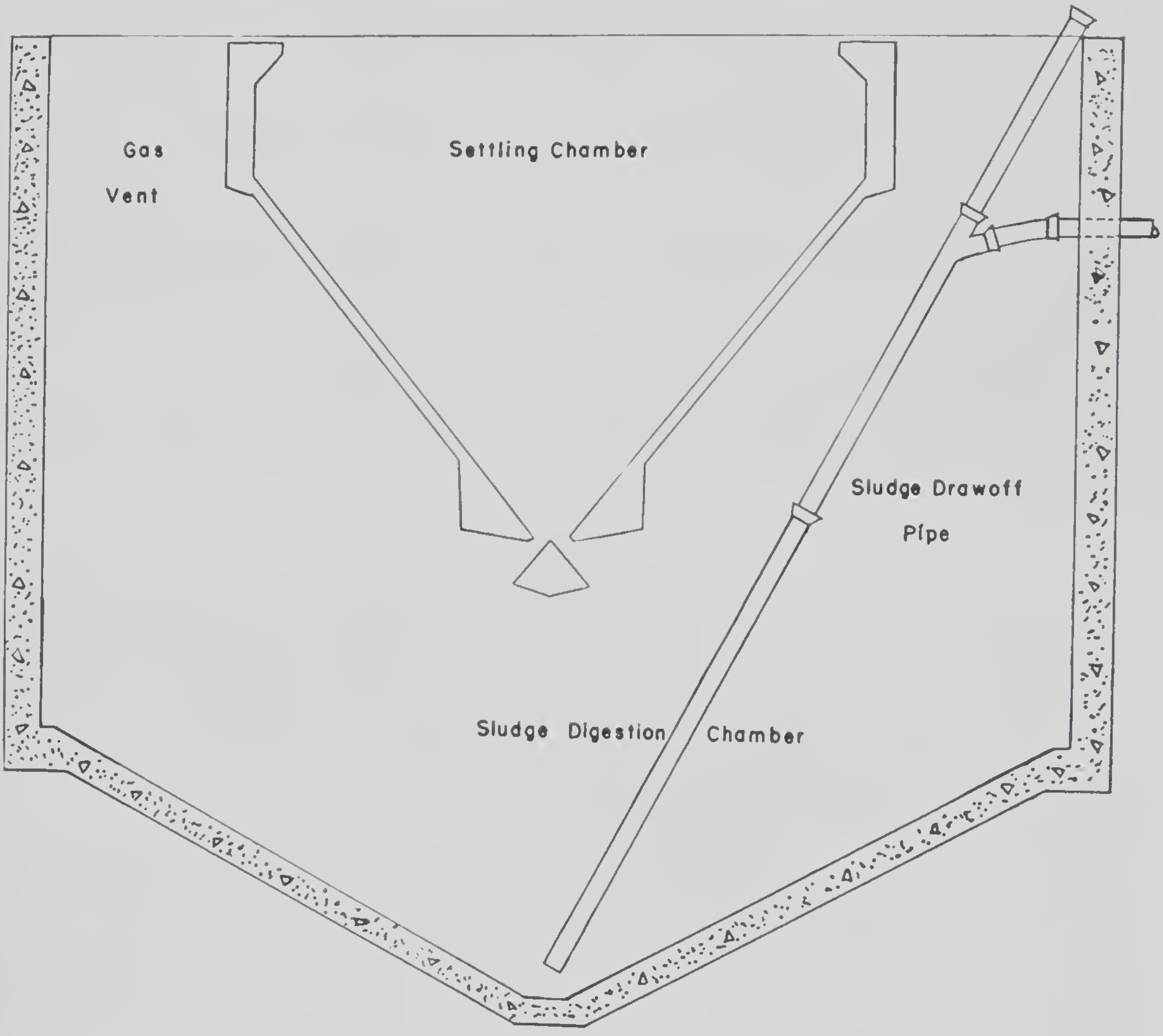


FIG. 52. Outline of Imhoff tank, Newark, Del. (Courtesy, Whitman, Requardt and Associates.)

Initial operation of an Imhoff tank should be in the summer when the temperature is high enough to promote rapid sludge digestion. A small amount of digested sludge is used to seed the tank and assure proper bacterial flora for best decomposition.

Scum and floating materials should be removed daily from the settling compartments. The sloping sides of these compartments should be squeegeed in order to loosen stranded solids. Any incrustation of material on the walls at or near the flow line should be removed. The sludge chamber should never be depleted of digested material. It is better to withdraw

small quantities of sludge at frequent intervals than a large amount infrequently. Only digested material should be removed from the tanks. Sufficient sludge must be removed at the end of warm weather to leave storage capacity over the winter. One difficulty with the operation of Imhoff tanks is their tendency to "foam". At such times a heavy viscous froth collects in the gas vents and rises to such a height that it often boils over into the settling compartment and sometimes passes off with the effluent. Foaming frequently occurs in the spring when there is a large accumulation of undigested sludge in the digestion chamber. As the temperature in the digestion chamber rises, digestion of the accumulated sludge proceeds at such a rapid rate that an abnormally large quantity of gas is produced. The sludge may become too acid, also; this too leads to foaming.

Sludge digestion in Imhoff tanks and subsequent drying are based upon the principles discussed on page 204 and 208.

Imhoff tanks are used for populations between 500 and 10,000. They are economical units for small communities.

## Primary Sedimentation

The object of primary sedimentation as applied in sewage treatment is to remove the suspended solids by simple sedimentation. The concentration of settled material that collects in the bottoms of the sedimentation tanks is called "sludge". When adequate diluting water is available, the effluents from primary sedimentation tanks may have a sufficiently low B.O.D. to permit disposal of the effluent without further treatment.

The conventional sedimentation tank is rectangular or circular. The velocity of flow through horizontal tanks is from 0.75 to 2.5 feet per minute. In the circular tanks using vertical flow, the rate of rise should be less than the subsiding rate of suspended particles, about 0.2 feet per minute. A depth of 10 feet is commonly used in the rectangular horizontal flow tanks. In these the sewage enters at one end of the tank, flows longitudinally through it and discharges at the opposite end. These basins are similar to those used in water treatment for subsidence.

The detention period should depend somewhat upon the treatment given to the effluent. If no further treatment is required, or if trickling filters are installed, a detention period of two to three hours is often adequate. A somewhat shorter period, ranging from one to one and one-half hours is generally provided when the effluent is treated by the activated-sludge process. At least two units are constructed to facilitate cleaning.

Primary sedimentation tanks will remove in excess of 50 percent of the suspended solids and 35 percent of the 5 day B.O.D. demand. With good

design to give efficient subsidence, the quantity of sludge deposited is in direct ratio to the concentration of suspended solids in the sewage. It averages about 4800 gallons per million gallons of sewage for separate systems and 3500 gallons for combined systems. The water content of the sludge is about 95 percent.

### *Manually Cleaned Tanks*

The small and older sedimentation tanks are usually emptied of sludge by manual operation. The tanks must be taken out of service and the clear supernatent liquid drained off. The sludge is removed through a special sluice gate in the bottom of the tank, or by laborers squeegeeing or flushing it to a sump from which it is pumped to the digestion tanks. Some tanks, instead of flat bottoms, have hoppered bottoms or V-shaped extensions below the usual bottom level. In hopper-bottomed tanks the sludge slides into the hoppers and is drawn off by hydrostatic pressure to the digestion tanks. Sludge should be removed every few days to prevent septic action and when discharged under hydrostatic pressure at least daily.

### *Mechanically Cleaned Tanks*

Several makes of equipment have been perfected for cleaning settling tanks without interfering with their operation. In the horizontal-flow tanks slowly moving scrapers or plows, driven by electric motors, are used. These move the sludge along the bottom of the tank to a sump or pit from which the material flows under hydrostatic pressure through a discharge pipe. One type of equipment which is used in the rectangular tanks consists of a series of scrapers or squeegees called flights, mounted between two power-driven endless chains which pass over a series of wheels at each side of the tank. As the chains rotate, the flights dragging on the bottom of the tank push the sludge to a depression at the inlet end of the tank. Figure 53. The flights rise and return toward the outlet end of the tank at the surface of the sewage, pushing any scum to a trough for removal. Electrically powered rotary scrapers known as clarifiers are used to clean square or circular tanks. Two or more structural steel arms (Figure 54) are suspended in the sewage just above the bottom of the tank. Attached to these arms are a number of short plows, that make contact with the bottom. The plows are set at an angle so that, as the equipment rotates, the sludge is moved towards the center of the tank to a sump, from which it is removed by pumping or hydrostatic pressure. If square tanks are used, the sewage flows in at one side and leaves at the opposite side. In the case of tanks that are circular, the influent enters at the center and flows radially outward over an overflow weir at the periphery. The floors in tanks of this type have a slight slope towards the center.

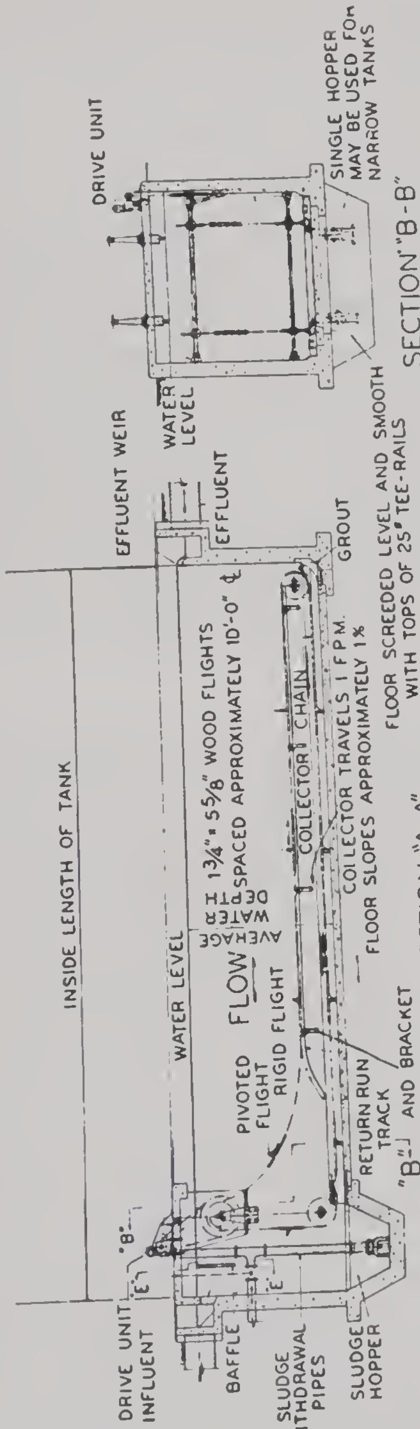


FIG. 53. "Straight line flow collector". (Courtesy, Link-Belt Co.)

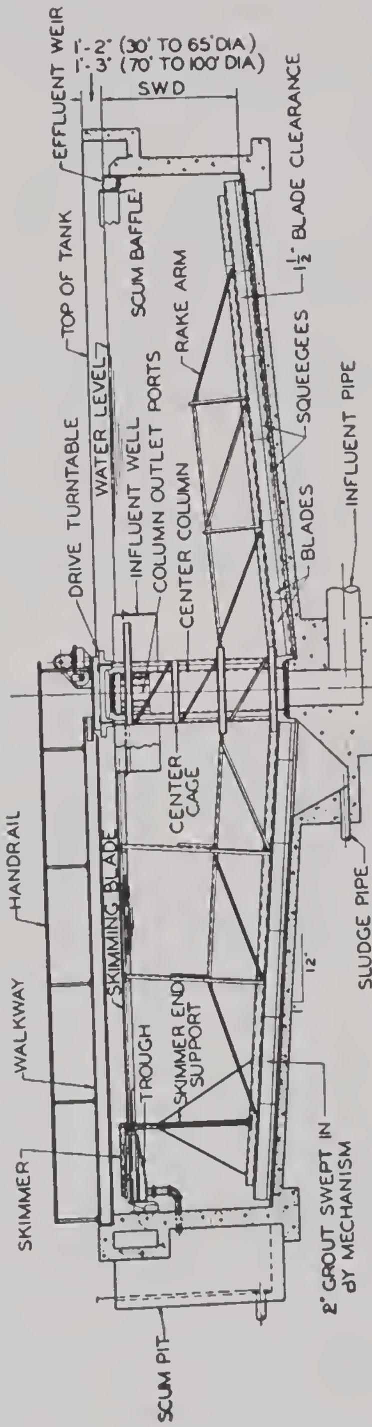


FIG. 54. Clarifier. (Courtesy, The Dorr Co. Inc.)

## Chemical Precipitation

Chemical precipitation is one of the oldest methods of sewage treatment, being widely used in England between 1880 and 1890. There has been a limited renewal of its use since 1930.

The method consists of the addition to the sewage of a suitable chemical to form a floc similar to that in the treatment of water prior to filtration through sand beds. Iron salts are usually used as a coagulant, although alum may be used. The settling floc increases the removal of suspended particles over the plain sedimentation process. In addition, the floc will remove much of the colloidal matter present. Chemical precipitation removes from 80 to 90 percent of suspended matter and bacteria, and 50 to 55 percent of organic matter.

When chemical precipitation is used, passage through a grit chamber and screens or a comminutor usually precedes the chemical treatment. Next, the chemicals in proper amounts are added in a tank called the flash mixer. The detention period is 1 to 2 minutes. The next step is a 20 to 40 minute period in a flocculation basin where the floc develops fully and is kept in constant agitation with the sewage through the use of paddle wheels or streams of air rising through the mixture. After the flocculation period, the sewage passes into a sedimentation chamber where the floc—with the suspended solids, colloidal matter, and bacteria—settles out and is withdrawn. The effluent may be discharged directly or given additional treatment by chlorine disinfection.

A chemical precipitation plant usually costs only a little more to construct than a plain sedimentation plant. The cost of chemicals is the chief operating expense. One method of economy followed at some sewage plants is to discontinue the use of chemicals in winter when the diluting water, into which the effluent is discharged, contains considerably more oxygen.

The chief objections to the process are the cost of chemicals, the formation of odors from the sludge, and the large amount of sludge produced. A decrease in the cost of coagulants and a better knowledge of colloidal chemistry has helped to offset these objections.

As is true of water purification, pH value plays an important role in the chemical precipitation of sewage. This factor varies with each sewage and individual studies must be made to determine the optimum point of coagulation for each. Operating data from several plants discloses that pH values approximating 9.0 are necessary for good flocculation.

**Quantity of Coagulants Used.** The quantity of coagulant required to give the best results varies not only at different places but also at the same point throughout the day. Determination of the best chemical and the amount needed is done on a trial and error test basis. The Coney Island, N. Y. treatment works averaged 272 pounds of copperas (ferrous

sulphate), 131 pounds of chlorine and 546 pounds of lime per million gallons. The Dearborn, Mich., works used 395 pounds of ferric chloride and 250 pounds of lime per million gallons.

## Intermittent Sand Filtration

The development and use of intermittent sand filters for the purification of sewage dates back to the studies of Frankland[6] in England, reported in 1870. In these experiments it was discovered that satisfactory purification could be accomplished at certain rates of flow through the beds, but that a resting or aeration period must be given between dosage cycles to obtain good results. This practice, based upon biological action, is utilized in modern installations.

The beds consist of a natural or an artificial layer of sand, varying in depth from 30 to 48 inches, with underdrains in the bottom having open joints. As a rule, two or more filters are provided. With this arrangement at least one unit can always be kept in service when it is necessary to repair or rest the other. A low bank usually surrounds each filter to prevent sewage from escaping.

In some instances raw sewage is applied directly to the filters. More frequently, however, the sewage is first treated in preliminary sedimentation tanks. At some plants the preliminary treatment consists also of contact beds, trickling filters, or activated-sludge units. The sewage is applied to the filters once or twice a day to a depth of about three or four inches. The quantity of sewage that can be treated depends upon its strength and the treatment given previously. Raw sewage can usually be applied at rates ranging from about 40,000 to 75,000 gallons per acre daily. If efficiently operated sedimentation tanks precede the filters, these rates may be increased 50 to 100 percent. Rates as high as 300,000 to 400,000 gallons per acre daily may be used when the sewage is first oxidized in trickling filters, or by activated-sludge units. The grains of sand in these beds become coated with a gelatinous film, which is filled with bacteria. This indicates that the treatment on intermittent filters consists of a straining action, supplemented with oxidation through biochemical processes, similar to that of the slow sand filter installation for water supplies.

The effluent from a well operated filter is quite clear, practically free from suspended material, and stable. Plants of this type are more generally used where a small number of persons is serviced, where land is cheap, or when a high grade effluent is required.

## Contact Beds

A contact bed consists of a water tight tank, filled with crushed stone, gravel, slag, or coke. The contact material varies in size from about 0.5 to

3 inches with a depth ranging from 4 to 6 feet. Drains with open joints are provided in the bottom for the withdrawal of the effluent. The sewage is generally first treated in sedimentation tanks to remove the major portion of the suspended material, and is then often passed through two or three contact beds in series.

The operation of contact beds falls into four periods: time of filling, time of contact, time of emptying and time of resting before refilling. The empty bed is filled with sewage and allowed to stand for an hour or two. During this period a considerable portion of the suspended and colloidal materials is retained on the stones. Then the sewage is drained off. Air is drawn into the beds, and the oxidizing effect of the bacteria is continued with a reduction of organic substances into stable compounds. The number of doses of sewage that can be applied to contact beds each day depends upon the strength of the sewage and the condition of the beds. Two to three applications a day are usually possible with a total dosage of about 500,000 gallons an acre daily.

As the effluent from these beds usually contains considerable suspended solids, final settling tanks should be provided to remove as much of this material as possible. Well operated beds should remove from 85 to 90 per cent of the suspended solids and from 60 to 80 percent of the biochemical oxygen demand. Contact beds are generally used at small plants. The effluent produced is not so good as that from trickling filters. One disadvantage with contact beds is the necessity of cleaning them every four or five years. This form of purification, however, produces fewer odors than do trickling filters. They are not used extensively now.

## Trickling Filters

The primary function of a trickling filter is the reduction of the oxygen demand of the sewage. The filter provides an opportunity for the oxidation of the putrescible material in the sewage by biological processes. It is capable of assimilating wide fluctuations in dosage and composition and will operate satisfactorily under cold weather conditions. Trickling filters are classified as a secondary or complete method of sewage treatment.

The development of trickling filters began with the investigations of the Lawrence Experiment Station in 1894.[21] The earliest installation in the United States was at Madison, Wis.[12] Operation of the Columbus, Ohio, works in 1908 proved the efficiency of trickling filters for winter service.

A trickling filter consists of a bed of crushed stone, gravel, slag, or similar material, laid on perforated ducts that form the underdrains of the system. The depth of the stone varies from 3 to 9 feet and the stones range in size from 1 to 3 inches. There must be good ventilation throughout the bed. The sewage is sprayed onto the top of the filter material either from

fixed nozzles in the filter bed or from long perforated metal arms that rotate horizontally a few inches above the surface of the bed. Either method results in an intermittent dosing cycle which permits alternate dosing and resting periods. The dosing period is usually regulated automatically. The liquid passes slowly over the surface of the stone in thin films, enters the underdrains at the bottom, and flows into an effluent pipe.

The sewage should be treated in sedimentation tanks before being applied to trickling filters, in order to remove most of the suspended solids; otherwise the distribution system and the filter stone will become clogged. A

FIG. 55. Trickling filters, Back River Sewage Treatment Works, Baltimore Md.

final sedimentation tank must follow the filter to collect the humus material that will slough off the filter media.

## *Action of Trickling Filters*

When a trickling filter is first put into service there is little improvement in the character of the effluent. As time passes, a gelatinous film filled with biological life, including many types of bacteria, protozoa, algae, larvae of flies, worms and spiders, forms on the stones. This biological conglomeration obtains its food from the organic matter in the sewage and so in metabolism, converts suspended, colloidal, and dissolved materials of a non-settleable and putrescible nature into stable nitrogenous products usually nitrates and nitrites that settle readily. The intermittent applica-

tion of sewage permits good circulation of air through the bed, thus encouraging the growth of aerobic organisms.[5]

During cold winter months the biological action in the filter will be appreciably retarded. This reduction in efficiency is generally compensated for by the fact that the final diluting water may be greater in volume and contain more dissolved oxygen at this period than in the summer when the filter efficiency is high.

Fig. 56. Trickling filter with rotary distributor. (Courtesy, The Dorr Co. Inc.)

Fixed nozzles and rotating sprayers are commonly used to apply sewage to the beds. With stationary equipment the influent flows through a series of distribution pipes which rest on or are immediately below the surface of the filter stone. Projecting above the stone a few inches and connecting with these pipes is a series of equally spaced nozzles. The sewage flows out through these nozzles, and falls on the stone in the form of a fine spray. With the use of automatic dosing devices, a section of the nozzle area delivers spray while other sections are quiescent. The sections are used alternately, permitting a cycle of dosing followed by a resting period. The cycles vary from three to five minutes, depending upon the season of the year and flow through the plant. Several types of moving spray nozzles

are used. The most common is the rotary distributor consisting of two or more tubular arms or pipes connected to a column in the center of the filter bed and around which they revolve in a horizontal plane. The outside ends of the pipes are supported by steel cables attached to the central columns. The partially treated sewage flows through a vertical pipe in the column to the horizontal pipes. The sewage flows through these pipes and out through equally spaced perforations in the bottom portions of the rotating pipes. The hydrostatic pressure of the sewage in the horizontal pipes serves to rotate the distributor arms about the vertical column as the sewage is discharged through the pipe nozzles. The movement of the arms results in an intermittent application of the sewage to the filter beds.

### *Filter Design*

Trickling filter capacity is based upon the removal of about 300 pounds of 5-day B.O.D. per acre to the depth of one foot. The size of the trickling filters to be used depends largely upon the strength of the influent being treated. Most filters are capable of satisfactorily treating the sewage from 2,000 to 4,000 persons per acre for each foot of depth. From 2,000,000 to 6,000,000 gallons per acre per day of settled sewage can be treated, the larger flows requiring deeper filters.

The selection of the proper size of stone is important. If small stones are used, less sewage can be treated; on the other hand, a better effluent can be obtained. One serious objection to small stones is the possibility of clogging in the beds.

### *Underdrains*

There should be a free flow of effluent from the filters during each cycle of operation. The floors of filters must be strong enough to bear the weight of the filtering material plus the maximum amount of water the filters are made to hold at one time. The floor should drain to a central diametrically placed drainage channel. Present construction methods use various types of hollow tiles constructed so that there are on the top of each tile slots about 1 to 1½ inches wide which lead into a duct running through the tile. When the tiles have been laid they cover the filter floor and the ducts in the tiles form a series of continuous drain lines leading to the drainage channel in the center of the filter bed. In operation, the sewage trickles through the filter media to the tiles where the liquids pass through the slots in the tops of the tiles to the drain lines formed by the tiles and then to the drainage channel. This system also serves as a ventilation system for airing the filters since the drain lines and drainage channel are designed large enough to prevent the liquid filling more than the drain lines and drainage channel by half the vertical area of the ducts. (In some cases the requirements permit even less liquid space.)

The filter bottom tiles are covered with the required depth of filter media, stone or slag, properly arranged according to the size needed.

Some of the older filters use perforated pipes as drain lines at the bottom of the filter media. The use of the tile described above gives better distribution and greater life.

### *Side Walls*

The side walls of trickling filters can be made of brick, tile, rubble masonry, or concrete; usually they are made of concrete. The height of the walls is such that they are 6 to 9 inches above the filter media surface, when rotary arm distributors are used, or 12 inches when spray nozzles are used.[10]

### *Operation of Trickling Filters*

Trickling filters require comparatively little attention. Spray nozzles that become clogged should be cleaned, and defective ones repaired. Filters that are overloaded sometimes become clogged with sewage solids and organic growths. One corrective measure consists in shutting off the flow to the clogged section. Much of the stranded material dries, and can be flushed out with the effluent when sewage is again turned on. Another effective way to clean filters is to add a large dose of chlorine to the influent for a few days. The chlorine disintegrates the slime, which passes off with the effluent. Picking or harrowing the surface stone is another method.

A large number of *Psychoda alternata* flies breed and live in trickling filters. The wind frequently blows these insects considerable distances from the sewage plant. This fly is so small that it will pass through most fly screens, and cause considerable annoyance. Elimination may be difficult so various methods are used. Spraying the outer walls or sides of the filter with a 5 percent solution of DDT in light oil or kerosene has marked benefits. The flies breed in the bed and migrate to the outer walls where they are killed. The residual fly density is then too low to cause annoyance.

### *Performance of Trickling Filters*

It is now believed that the B.O.D. test gives the best information on filter efficiency. It is known that the rate of oxidation decreases with increasing filter depth and for this reason efficiency is not rated in B.O.D. removal per foot but per acre, since the latter includes the entire filter depth. This is illustrated in Table 13.

Data taken from 21 efficiently operated treatment works indicate that trickling filter effluents average 55 ppm. suspended solids and 32 ppm. 5-day B.O.D. or a reduction in B.O.D. of 80 percent and in suspended solids of 40 percent.

## Secondary Sedimentation

The action of sewage filters is due to the prolific growths of organisms in the filter media. The biological action of these organisms converts the non-stable, non-settleable components of the sewage into relatively stable, readily settleable products which are given off continually in the filter effluent. The filter effluent must have a final period of sedimentation to permit removal of this humus-like suspended matter. Several tests have shown that secondary sedimentation will remove an appreciable amount of B.O.D.

The design of secondary settling tanks follows the general principles used in designing the primary sedimentation tanks. The sludge collected can either be pumped directly into sludge digestion tanks or it can be

TABLE 13

*Comparative Quantities for Various Expressions of Filter Loading*

| Per Acre Filter 6 Ft. Depth | Expressed as Pounds Per Day 5 Day B.O.D | | |
|---|---|---|---|
| | Per acre foot | Per 100 cu. ft. stone | Cu. ft. stone per pound B.O.D. |
| 1200 | 200 | 4.59 | 218 |
| 1500 | 250 | 5.74 | 174 |
| 3000 | 500 | 11.48 | 87 |
| 6000 | 1000 | 22.95 | 44 |

Langdon Pearse et. al., "Modern Sewage Disposal", p. 58, Federation of Sewage Works Assoc., N. Y., 1938.

reintroduced into the raw sewage before passage through the primary settling tanks.

## Bio-Filters

A bio- or high-rate filter is an adaptation of the trickling filter operated at a high average daily dosing rate usually between 10 and 30 million gallons per acre. The filter effluent is recirculated usually to the influent of the primary sedimentation tank. Because of the increased oxygen demand of these filters a shallow bed with increased free air between the interstices of the stones is more effective than the conventional trickling filter. The process permits reduction in the size of filter units by using a much higher dosing rate than for the low-rate filter. Recirculating the filter effluent to the primary sedimentation tank so that it passes through the filter more than once makes it possible to reduce the B.O.D. in amounts equal to the low-rate filter results. Another advantage is that recirculation of the filter effluent to the sedimentation tank prevents the raw sewage from

becoming septic. Some raw sewages show a marked tendency to form scums in the primary settling tank. The scums interfere with efficient operation; recirculation reduces scum formation.

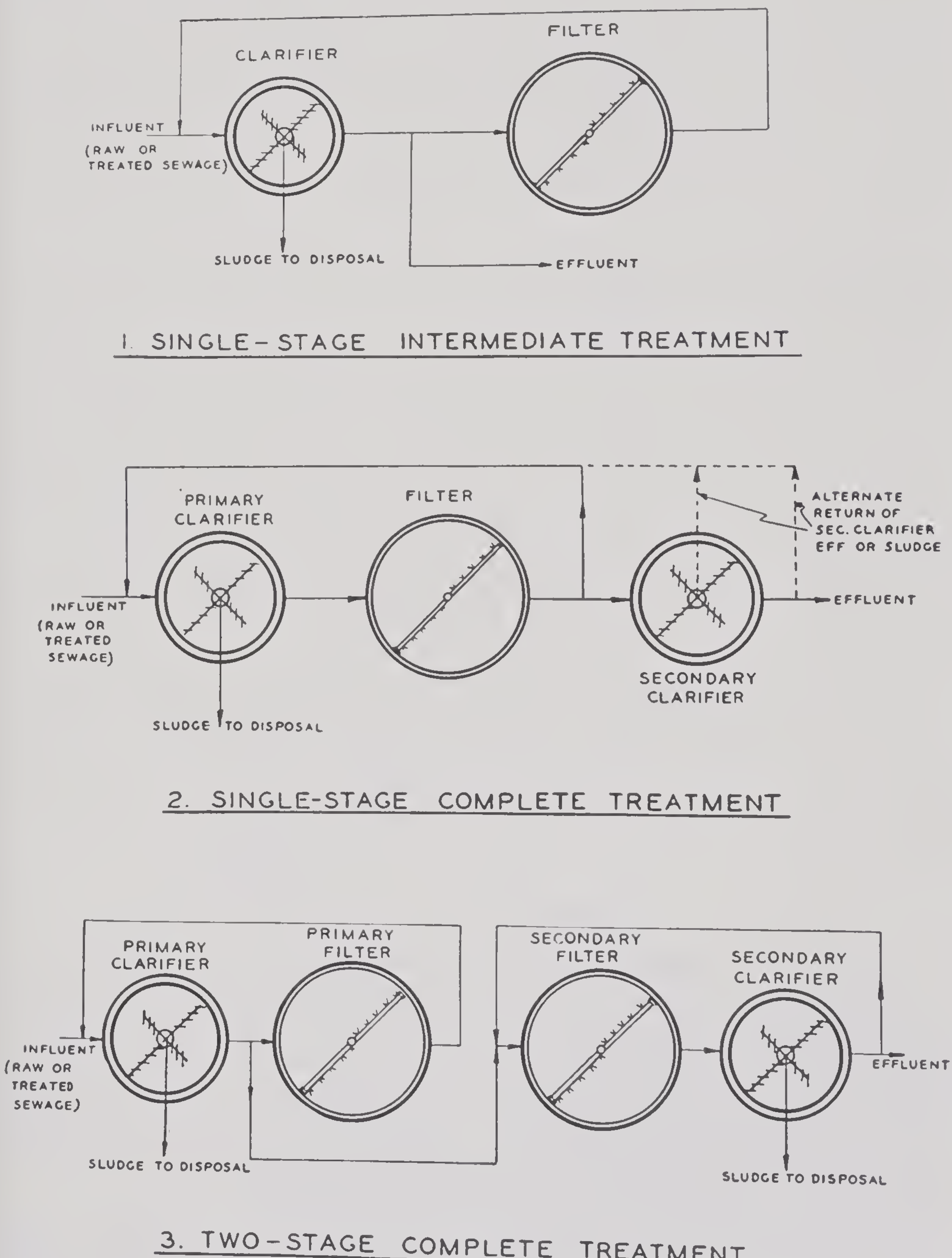


FIG. 57. Diagram showing outline of bio filtration treatment. (Courtesy, The Dorr Co. Inc.)

Some plants are equipped with a second high-rate filter and clarifying tank. Better treatment of the sewage is obtained through greater flexibility in operation and more complete stabilization. This is called two-stage treatment.

The beds are normally circular and 3 to 4 feet deep with rotary distributors to provide nearly continuous dosing. Stone, drains, and other construction features are similar to the conventional trickling filter. Since the high-rate filter handles much greater quantities of liquid than the conventional filter, proper grading and selection of filter media is more important.

The recirculating cycle is from the filter to the inlet of the primary sedimentation tank (single stage); or part from the primary filter to the primary sedimentation tank inlet and the balance directly to the inlet of the secondary filter (double stage). A portion of the effluent from the secondary clarifier is usually recirculated to the inlet of the secondary filter.

Five day B.O.D. applications are at the rate of 3000 pounds per acre foot and recirculating ratios of sewage returned to new raw sewage flow vary from 1:1 to 4:1, based upon the strength of the sewage and the recirculating cycle. Table 13.

Operating results indicate that the efficiency of single stage units is comparable to the trickling filter while double stage units equal activated sludge treatment.

Effluents from single stage units average 126 ppm. suspended solids and 170 ppm. 5 day B.O.D. or a reduction in B.O.D. of 62 percent and in suspended solids of 53 percent. Double stage units average 40 ppm. suspended solids and 30 ppm. 5 day B.O.D. or a reduction in B.O.D. of 95 percent and in suspended solids of 90 percent. A final settling tank should follow the last filter.

## Activated Sludge Treatment

The activated sludge process is a development of the preliminary investigations by Clark[4] at the Lawrence Experiment Station in 1912. These investigations were elaborated upon by Arden and Lockett[1] in Manchester, England and continued in this country by Bartow and Mohlman.[2] The perfecting of the process to its present status has been the results of the combined efforts of engineers and chemists in this country and abroad. Large plants have been built in many cities, including Milawukee, Wis., Chicago, Ill., Indianapolis, Ind., and Cleveland, Ohio.

The process consists of bringing air into intimate contact with sewage, to which biologically active sludge, a product of the process, has previously been added. The air in the activated sludge process maintains

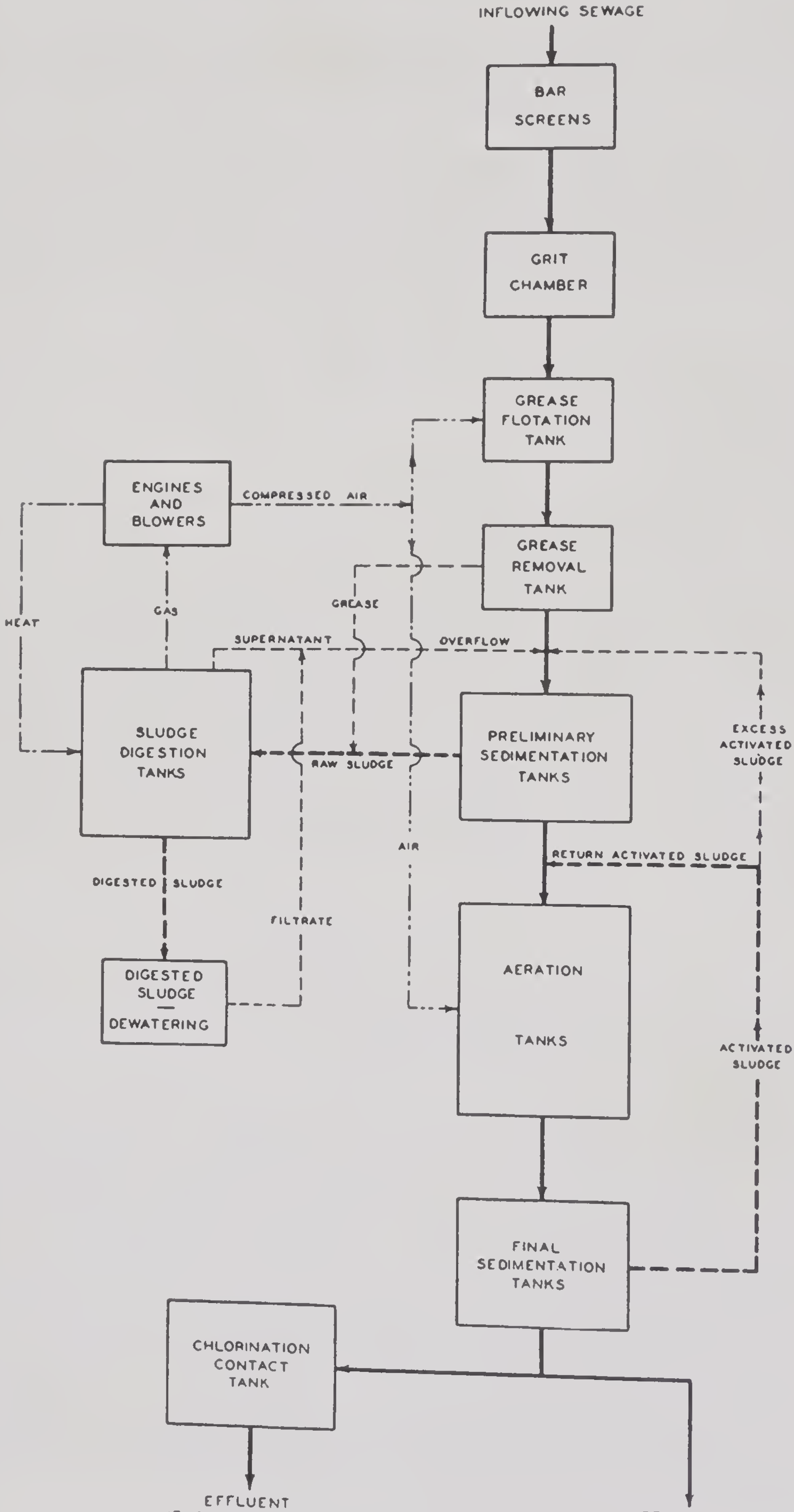


FIG. 58. Diagram typical activated sludge treatment works

aerobic conditions, keeps the sludge in suspension, and by constant agitation of the mixture, allows unactivated liquid to come in contact with the sludge. Buswell[3] describes the process:

> "If one examines particles of activated sludge under the microscope he is immediately impressed with the fact that there is practically no absorbed, precipitated or coagulated amorphous matter in these sludge particles, but that they are composed entirely of active, growing microscopic organisms of varieties ranging from true bacteria up through the giant bacteria, with occasional molds and yeasts, and also a variety of free swimming and attached protozoa."

These communities of micro-organisms must obtain food and this food is supplied from the colloidal matter and dissolved salts in the sewage. Keefer states:[11]

> "Three requirements are essential in the activated sludge process:
> (1) an adequate supply of air;
> (2) activated sludge and
> (3) thorough mixing or stirring of the sludge with the sewage.
> Air maintains aerobic conditions; it also keeps the sludge in suspension and mixes the sewage and sludge where diffused air is employed. There is considerable evidence to indicate that the sludge absorbs organic compounds in the sewage and that the absorbed material is oxidized bio-chemically. First the carbonaceous compounds are oxidized, and if the treatment is continued, the nitrogenous materials are converted into nitrites and nitrates. Agitation, which is an important feature of the process, breaks up the surface of the sewage and aids in the solution of oxygen from the atmosphere. Agitation also brings oxygen, dissolved organic matter and colloidal particles in contact with the activated sludge floc."

*Preliminary Treatment*

Treatment with coarse bar screens and grit chambers is an essential preliminary step in activated-sludge plant operation. Fine screens and primary settling tanks are also frequently installed.

One method of treatment consists of blowing air through the sewage in aeration tanks for 4 hours or more. The biologically active sludge, called activated sludge, is added to the influent flowing to the aeration tanks in amounts varying from about 15 to 35 percent by volume of the sewage.

After the sewage and the sludge have been sufficiently aerated, the mixture flows through settling tanks, where the sludge settles out, leaving a practically clear effluent with a 5-day B.O.D. of from 15 to 25 ppm. The sludge is removed from the settling tanks, the required portion for seeding being pumped back into the influent to the aeration tanks. The remainder, called excess sludge, is dewatered in one or more ways, or is pumped into the raw sewage, and removed with the sewage solids in the preliminary settling tanks.

*Aeration*

After admission to the aeration tank it is essential that the flow of activated sludge and raw or partially treated sewage come in contact with the air and that a sufficient velocity be maintained to prevent subsidence of the sludge. Air under pressure is brought to porous tubes or plates in the bottom of the tank and rises in bubbles of very small dimension through the mixture of sludge and sewage, escaping to the atmosphere at the surface of the liquids. Porous plates have been widely adopted, as the best

TABLE 14

*Quantity of Air Necessary for Activation of Sewage*

| | Cu. Ft. of Free Air per Gallon of Sewage |
|---|---|
| 1. For rather weak domestic sewage | 1.0 |
| 2. For strong municipal sewage containing some industrial wastes not particularly detrimental to bacterial life | 1.5 |
| 3. For weak municipal sewage containing considerable industrial wastes, some of which are detrimental to bacterial life, as for example, acid-iron wastes | 2.0 |
| 4. For strong municipal sewage containing considerable industrial wastes, some of which are detrimental to bacterial life, as for example, acid-iron wastes | 4.0 |
| 5. For municipal sewage containing sufficient industrial wastes, not specifically inhibitive of bacterial life, to influence decidedly the composition of the sewage, e.g., packinghouse, tannery, etc. | 3.0 |
| 6. For strong packing house wastes | 4.0 |
| 7. For strong tannery wastes containing a very large proportion of colloids, but settled before aeration | 6.0 |

"Sewerage and Sewage Disposal", Metcalf and Eddy, 2nd ed., p. 659, McGraw-Hill, 1930.

way to obtain good diffusion of the air as it enters the sewage. Several plates, each about 12 inches square and 1 inch thick are set in a holder made of concrete, cast iron, or aluminum. The air pipe is attached to one end of the holder. The escaping air imparts a spiral motion to the sewage resulting in smaller air requirements.

Motor or gasoline driven blowers are employed to compress the air. The volume required is noted in Table 14. A concentration of 1 ppm. of dissolved oxygen is necessary to maintain a satisfactory effluent from the aeration tank. The air is cleaned by washing and passing through cloth filters before passing to the diffuser plates as a means of preventing clogging of the plates. Paddle wheels are used as a substitute for compressed

air in obtaining agitation and aeration of the sewage. They may also be used in conjunction with compressed air.

The size of aeration tanks depends upon the strength of the sewage and the quantity of returned activated sludge. The number of tanks is in direct proportion to the volume of sewage. There should be a sufficient number so that one or two can be kept out of service without materially decreasing the retention period in the other tanks. A working depth in the tanks of 15 feet is often used. Widths of tanks are 1 to 1½ times the depth.

The average concentration of solids in the aeration tanks (mixed liquor) usually varies between 2000 and 3000 ppm. with a return of activated sludge averaging 29 percent of the sewage flow. (Solids concentrations of 5000 to 10,000 ppm. have been found highly effective but difficult to

TABLE 15

*Performance of Activated Sludge Plants*

| City | Sedimentation Tanks Effluent from Final (*ppm.*) | | Percent Reduction | |
|---|---|---|---|---|
| | 5 day B.O.D. | Suspended Solids | 5 day B.O.D. | Suspended Solids |
| Houston, Tex. | | | | |
| North Side plant | 32 | 37 | 83 | 81 |
| South Side plant | 39 | 44 | 79 | 77 |
| Indianapolis, Ind. | 20 | 32 | 91 | 84 |
| Milwaukee, Wis. | 12 | 18 | 96 | 94 |
| Springfield, Ill. | 13 | 12 | 91 | 92 |

C. E. Keefer, "Sewage Treatment Works", McGraw-Hill, N. Y., 1940.

maintain.) The sludge must be kept fresh and not allowed to become septic. An odorless effluent with a high degree of purity can be obtained by this process. The efficiency of the process and the character of the effluent is given in Table 15.

It will be noted that the 5-day B.O.D. does not exceed 16 ppm. and the suspended solids 26 ppm. This high degree of purification, together with minimal space requirements and low installation cost, frequently offsets high operating charges, justifying the wide spread adoption of this procedure.

## Final Sedimentation Tanks

The detention period in final sedimentation tanks, also known as humus tanks, varies from 3 hours for trickling and bio-filter effluents to 1½ hours for activated sludge effluents. Velocities of flow through the tank must not exceed 2½ feet per minute. About 500 gallons of sludge per million gallons of effluent are deposited from trickling and bio-filters.

Sludge must be withdrawn at frequent intervals to keep it from becoming septic. The sludge which settles out of the effluent from trickling filters is discharged to sludge digestion tanks or to the primary settling tank where it settles out with the raw sewage sludge. Sludge settling in sedimentation tanks, following treatment in activated sludge tanks, is sent to the primary sedimentation tanks, sludge digestion tanks, returned to the aeration tanks as activated sludge, or dried by vacuum filtration. Continuous sludge removal equipment with either straight flow collectors or rotating clarifiers as described for primary sedimentation tanks may be utilized in these tanks.

## Disposal of Final Effluents

The treatment given sewage should reduce the suspended solids and B.O.D. so that the particular effluent will be assimilated by the receiving stream or other body of water. Unless this treatment is accomplished, septic conditions with foul odors, and sludge deposits will develop in the receiving body of water. Such situations are caused by insufficient diluting water, lack of dissolved oxygen, absence of aerobic organisms and settleable solids in the effluent. The quality of the effluent should depend upon the nature of the receiving water. If the discharge flows into a stream that later serves as a source of drinking water, a high quality effluent should be required. If the stream carries much waste or is not used for drinking water supplies, recreation, or fishing, a poorer quality effluent may be permitted.

Chlorine is added to sewage effluent to reduce B.O.D. and odors. Chlorination of effluents will reduce the biochemical oxygen demand 2 parts for every ppm. of chlorine applied,[13] and give a stable effluent that will not become septic. It is often desirable to chlorinate sewage plant effluents as a supplement to the normal process during the summer when stream flow is low and dissolved oxygen at a minimum. The quantity of chlorine added is usually from 5 to 20 ppm. to provide a chlorine residual after 30 minutes of 0.2 to 0.5 ppm.

Effluents from sewage treatment plants are occasionally utilized for industrial process water. This is practical when an adequate supply of water from normal sources is unavailable. The volume of effluent must be sufficiently large to continuously meet the industrial demand and the cost of conditioning the effluent must be reasonable.

Sewage effluent has been furnished the Rock Island Railroad for boiler use at Herrington, Kan., since 1934[23]. Substitution for condenser water in oil refineries has been noted at Bring Spring, Tex., and Enid, Okla. while at Goldfield, Nev. it is used in a metallurgical process.

The Sparrows Point plant of the Bethlehem Steel Co. uses 70 mgd. of effluent from the Back River Treatment Works at Baltimore, Md. Activated sludge or trickling filter effluent is treated with alum, followed by sedimentation and chlorination with subsequent discharge into the industrial water system of the steel plant[24]. A comprehensive program for similar use of sewage effluents has been proposed in Los Angeles County, Calif.[25]

## Odor Control

Sewage odors are principally hydrogen sulfide, caused by the decomposition of organic sulfur compounds. Concentrations below 1 ppm. are not obnoxious. Wind velocities of 15 miles per hour will distribute odors to areas adjacent to the sewage plant and cause nuisances and complaints.[7]

Chlorine is commonly used as a deodorant since it combines directly with hydrogen sulfide. The disinfectant action of the chlorine also inhibits bacterial action and prevents gas production. It is applied to the raw sewage in outfall sewers to prevent disintegration of the concrete by the action of sulfuric acid formed from the hydrogen sulfide, and to the effluent from trickling filters for odor neutralization. An average dose of 5 ppm. will deodorize sewage effluents but will not retard normal biological processes.

## Sludge Digestion

The final water content of sludge is directly related to the preliminary treatment. Activated sludge with a water content of 98.5 percent produces the greatest sludge volume.

The object of sludge digestion is to produce an unobjectionable, stabilized material that can be dewatered and disposed of in some convenient and inexpensive way—by burial, by incineration, or by use as fertilizer.

Raw sludge is highly putrefactive and objectionable. When kept in the proper environment, it gradually decomposes, or digests. Digestion is caused by anaerobic bacteria which obtain their supply of oxygen from organic or mineral compounds. During digestion the sludge loses its disagreeable odor, and its color changes from a light brown or gray to a dark brown or black. Digested sludge when dry has a fine, granular consistency and a not unpleasant tarry odor. In the digestion process a considerable portion of the organic material is liquefied and gasified. The volatile solids in raw sludge vary from 60 to 80 percent (dry basis) before digestion and from 40 to 55 percent after. Digestion usually reduces the volume of solids by 40 or 50 percent. Thus, it can be more readily dewatered on sludge drying beds than can raw sludge.

Sludge digestion passes through two separate stages. The initial phase is an acid one with a pH varying from 5.1 to 6.8. During this period the carbohydrates are decomposed, while fats and proteins are hydrolized.

Hydrogen sulfide evolves and a rapid generation of large quantities of carbon dioxide occurs. During this rapid evolution of gas a foamy scum may be formed. The resultant sludge in this stage is viscous and sticky. The second phase is an alkaline digestion resulting from the decomposition and reduction of proteins, amino acids, and other complex nitrogenous compounds to ammonia and methane. The pH is between 6.9 and 7.4,

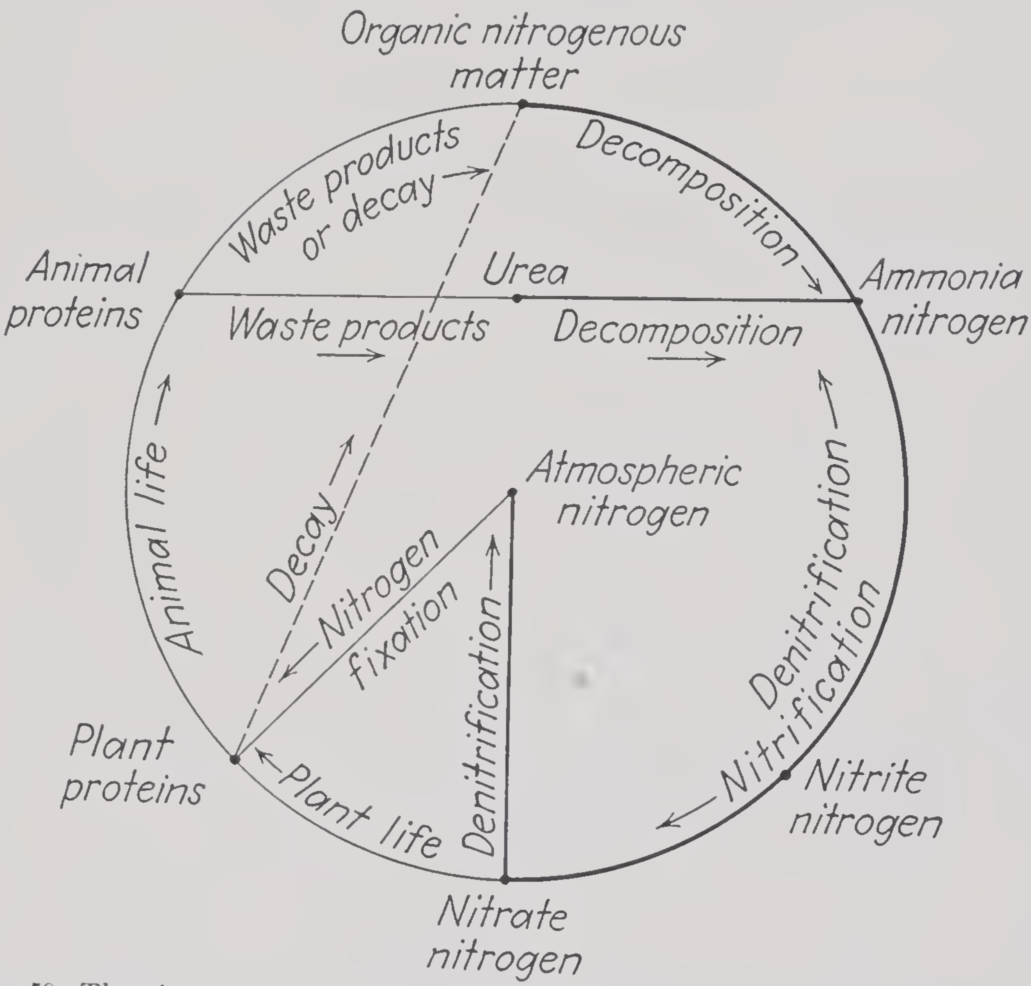


FIG. 59. The nitrogen cycle. ("Sewage Treatment Works", C. E. Keefer, McGraw-Hill, p. 49, 1940.)

foaming ceases and there is only a slight tarry odor. The gas produced will contain from 65 to 85 percent of methane, the remainder being carbon dioxide and a small quantity of hydrogen sulfide.

The process of digestion is in conformity with the nitrogen and carbon cycles of natural decomposition. The nitrogen cycle, so termed, is the system depicting the natural changes occurring in the process of stabilization of nitrogenous products. In this system the unstable ammonia is converted to nitrites by bacteria and then by oxidation to the stable nitrates. The unstable nitrogenous materials are obtained from the initial breakdown of proteins and other forms of animal matter. The stabilized

nitrates are then available as fertilizer for the reproduction of plant life which in turn supports the animal life, supplying the protein for a renewal of the cycle.

The carbon cycle is a breakdown of the carbohydrates and cellulose products by enzyme action to carbon dioxide and water. The carbon dioxide is then in turn assimilated by the chlorophyll of plant life, re-

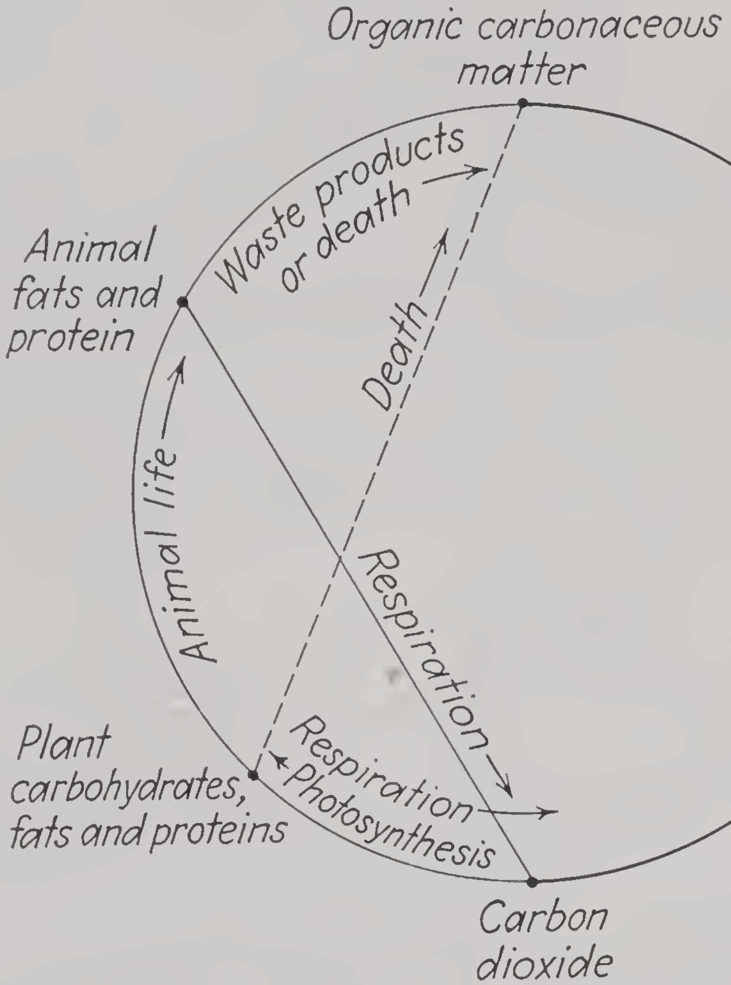


FIG. 60. The carbon cycle. ("Sewage Treatment Works", C. E. Keefer, McGraw-Hill, p. 50, 1940.)

creating new cellulose and other carbon products, which are converted by the animals using this form of food into tissue to be later broken down into cellulose waste products.

The factors that influence digestion are the pH value of the sludge, the presence of digested material for seeding or inoculating the raw solids with desirable bacteria and temperature. Most sludges digest best when the pH value is between 7.0 and 7.6. When a sewage plant is first put in operation or when the ratio of raw to digested sludge is high, lime is often used to adjust the pH value, which frequently is as low as 5.0 when digestion is uncontrolled.

A considerable quantity of digested sludge should be present in order to seed the raw solids. It has been found that not over four or five percent of undigested solids by weight on the dry basis, can be added daily to sludge digesting at a temperature of from 85° to 100° F.

One of the most important factors that affects the digestion process is temperature. The best practice seems to be to keep sludge somewhere between 85° to 100° F.

At this temperature digestion will be complete in approximately 30 days. Laboratory experiments and some field studies have been made with digesting sludge at temperatures between 125° and 145° F. Under these conditions digestion is finished in about 12 days. The digestion of sludge at these temperatures has not as yet been satisfactorily worked out on a practical basis. The heat required is obtained by burning the gas produced by the digesting sludge.

### *Digestion Tanks*

Long before the present knowledge regarding the decomposition of sludge was established, sludge was digested in septic and Imhoff tanks. Two of the oldest digestion tank installations are those in Baltimore, Md., and Birmingham, England.

Digestion tank capacity varies with the preliminary treatment and the amount of heat furnished during the digestion. Unheated tank capacity ranges from 3 cubic feet per capita for primary sedimentation sludge to 6 cubic feet per capita for activated sludge. Heated tank capacities similarly vary from 2 cubic feet to 4 cubic feet. Unheated tanks require at least 90 days capacity for storage during the winter months when digestion practically ceases.

Sludge digestion tanks are commonly built of concrete with depths normally in excess of 20 feet. Depth is necessary to assure good digestion and provide space for gas collection and liquefaction. The tanks are usually circular although square ones have been installed. When gas from digestion is collected for heating purposes or generation of electricity, the digestion tanks must be equipped for the collection of the gas. The top is said to "float" and is free to move up and down, coinciding with the quantity of gas in storage. Tanks with fixed covers are also used. They are equipped with gas collection domes. Since methane gas is available to furnish hot water, most covered tanks are also heated. Heated tanks are protected by earthen banks piled against the walls to reduce heat losses due to radiation.

Sludge digestion provides a daily average of 0.75 to 1.0 cubic feet of gas per capita. This gas contains from 65 to 70 percent methane, 15 to 30 per cent carbon dioxide, and small amounts of hydrogen sulfide, nitrogen, and hydrogen. The heat value averages 750 B.t.u. per cubic foot. The gas is

collected from the tank domes and stored in a steel holder tank. Excess gas not needed for heating or other operations is burned.

The most important use for the gas is heating the digestion tanks. Water is heated with household types of heating equipment to a temperature of 140° F. and pumped through coils in the digestion tanks to maintain the sludge at the desired temperature. Figure 61. Sludge is also heated by injecting steam into the sludge before it enters the digestion tank.

In addition to heating sludge tanks, gas is also utilized for operating gas engines for the generation of electricity. Many installations have been

Fig. 61. Heated sludge digestion tanks showing hot water coils

made in the United States and Europe. In some instances sufficient power is generated so that none need be purchased.

## Sludge Dewatering

Digested sludge is withdrawn from the tanks at definite intervals and dewatered. Considerable quantities of digested sludge must be retained in the tank to serve as a source of biological flora to assure continuous digestion of the raw sludge pumped in each day. When sludge is removed from the digesting tanks it contains from 90 to 96 percent water, with the exception of fresh activated sludge which may have 98 to as high as 99.5 percent water. The sludge is dewatered to reduce the volume to be handled and also to put it into a condition for easier handling.

### *Sludge Drying Beds*

For many years most kinds of sludge have been dewatered on sludge drying beds, either open or covered. Open beds are made of a layer of sand or cinders a few inches thick, usually with gravel underneath. Pipes with open joints are generally provided below the sand layer of the bed, to collect the liquids that seep out of the sludge and pass through the sand. The beds are enclosed by low earth banks or concrete partitions and as a rule are divided into compartments that vary in width from 15 to 25 feet with lengths up to 150 feet or more. One square foot of drying area per capita is required for open beds and $\frac{1}{2}$ square foot per capita for covered beds.

The wet sludge, which preferably has been digested, is applied 8 to 12 inches thick. In about 2 weeks during the summer the water in the sludge evaporates and drains off sufficiently for the dried material to be removed. The moisture in the sludge "cake" will depend to a considerable extent upon the length of time the sludge has been drying. It is common practice to remove the cake after its moisture has been reduced to from 55 to 65 per cent. Except in the southern part of this country, sludge can be dried only during eight or nine months of each year. As soon as a sludge bed has been cleaned, wet material is again put on the bed. From 6 to 10 applications can usually be made yearly.

Covered sludge beds are sometimes used in place of open beds. The only difference between covered and open beds is that the former are provided with glass enclosures similar to those used for greenhouses. Covered beds allow the sludge to dry during wet weather and there is less likelihood of odors escaping from the sewage plant, in case partially digested material is being dried. Furthermore, less area is required when covered beds are provided. The chief disadvantages of covered beds are their high first cost and the fact that midday temperature within the enclosure in summer is often so hot men cannot work there.

### *Vacuum Filters*

One method of dewatering sludge that has not been digested is the use of the vacuum filter (Figure 62) which consists of a cylindrical drum covered with a cotton or woolen cloth and rotated on a horizontal axis. The lower portion of the drum projects down into a trough into which sludge is flowing. A vacuum is applied to the inside of the drum, causing a thin layer of sludge to adhere to the cloth. As the drum rotates, water is sucked through the cloth, leaving a thin moist cake which is scraped into some type of receptacle. Activated sludge cake usually contains from 80 to 84 percent moisture.

As the material in this condition has not undergone decomposition and is

quite putrefactive, it must be disposed of quickly or given further treatment. Chemically precipitated sludges are also dewatered on vacuum filters. The sludge cake generally contains from 65 to 70 percent moisture. Filters are also well suited to dewater digested sludge.

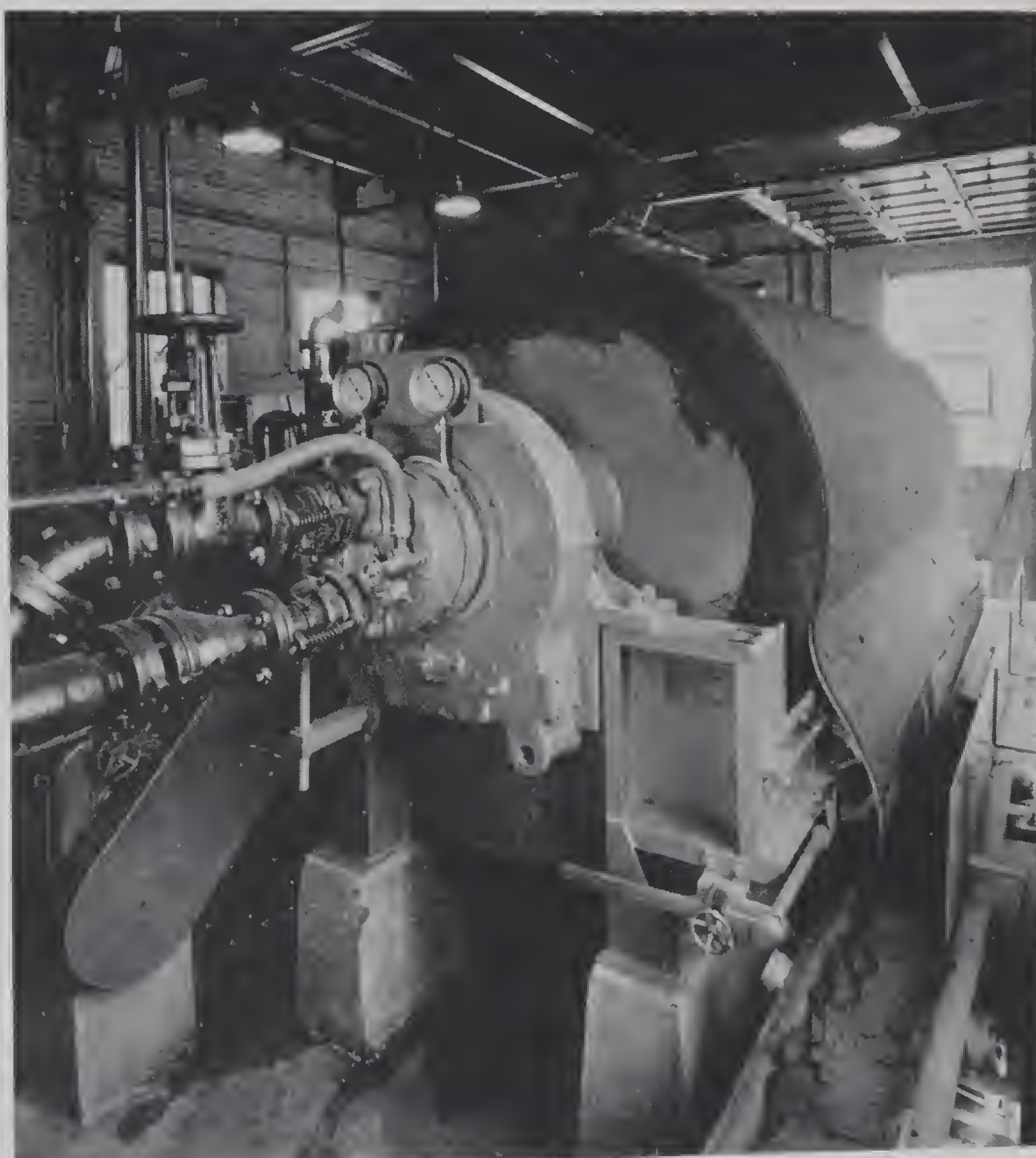

FIG. 62. Vacuum filter for sludge dewatering. (Courtesy, Oliver United Filter, Inc.)

Before sludge is filtered, it must be "conditioned" by coagulation with one or more chemicals. Ferric sulfate, chlorinated copperas, ferric chloride, and ferric chloride and lime are most generally used. Of these ferric chloride and ferric chloride and lime give the best results. The quantity of coagulant required depends upon the kind of sludge being dewatered, the

concentration of ammoniacal compounds present and other factors. Less coagulant is required with fresh than with digested sludge. A higher filter yield can be obtained when dewatering digested material than when raw or activated sludge is filtered. Sludge drawn directly from primary sedimentation tanks or from activated sludge tanks, without conditioning, will not dewater readily.

Vacuum filters are superior to drying beds in many ways. The area required for sludge beds is many times the space needed for vacuum filters. Furthermore, personnel requirements to operate drying beds are higher. Cost estimates indicate that vacuum filters are cheaper to operate than drying beds where large installations are required. The process is utilized in large cities and is also economical for small installations. Chicago, Ill., Cleveland, Ohio, Baltimore, Md., New York, N. Y., Minneapolis, Minn., Buffalo, N. Y., and Detroit, Mich. are some of the larger ones using vacuum filters.

### *Elutriation and Pre-conditioning*

Genter[5] has demonstrated that the normal concentrations of soluble ammonia and amino nitrogen compounds found in sewage inhibits the flocculating value of the coagulants to "condition" it prior to vacuum filtration. He also proved that these soluble products could be washed from the sludge with water or sewage effluent. It is now known that these compounds are ammonium bicarbonate.[20] This washing process is known as elutriation and consists of diluting and thoroughly washing the sludge with water to dissolve the decomposition products, sedimentation, and a subsequent decantation of the wash water, termed elutriate.

The amount of coagulant needed for conditioning or to make more easily dewaterable the sludge solids, will be reduced by elutriation from 60 to 80 percent. This reduction is due to the washing out of those nitrogenous compounds which would otherwise combine with the coagulant.

One volume of sludge is usually diluted with two or three volumes of water or sewage effluent, thoroughly mixed and allowed to settle. The liquid portion is then removed and the settled material passed to the coagulation tanks for "conditioning" with the coagulant. The process was first adopted at Baltimore, Md. Other installations are in operation at Hartford, Conn., Greensboro, N. C., Winnipeg, Manitoba, Canada, and Washington, D. C.

## Disposal of Sludge

Sludge can be disposed of as dried, digested, stable material; dried, fresh sludge that will become offensive when wet; fresh sludge as drawn from a primary or secondary sedimentation tank.

**Dried, digested sludge.** The material obtained by drying digested sludge on sand beds can be burned, buried, or used as fertilizer. When burned, separate incinerators used just for that purpose may be used or the sludge may be burned along with garbage or refuse from the city. Properly designed and operated incinerators should be able to dispose of sludge without the production of any nuisances. The remaining ash is wholly stable and unobjectionable.

Dried sludge can also be buried. Natural pits or depressions are usually used as the site for this type of disposal. Very little in the way of nuisances should be caused by this method of disposal.

Use of sludge as fertilizer appeals to many because of the conservation of any fertilizer value in the sludge plus the fact that it is frequently a cheap method of disposal. Many sewage plants offer dried sludge to farmers and charge nothing for it, but the farmer must carry the sludge from the plant. The sludge obtained from an Imhoff tank or from primary sedimentation tanks is not very high in desirable plant food constituents if the usual chemical elements, nitrogen, phosphorus and potassium, only, are considered. An analysis of such sludge, on a dry basis, would give widely varying results but would show approximately: total nitrogen 2.0 percent; phosphates 1.0 percent; and, potash less than 1.0 percent. The sludge is good in that it has bulk and it also contains traces of various elements necessary for good plant growth.

**Dried, fresh sludge.** Sludge from the activated sludge process that has not been digested is frequently dried. This is the case when the sludge from the sedimentation tanks is extracted on vacuum filters or in clarifiers, conditioned, and dried on sand beds.

Since the unstable components of the sludge have not been stabilized by digestion, sludge of this nature may become offensive under certain conditions. In general, it is disposed of in the same ways as the dried, digested sludge.

The fertilizer value of sludge from the activated sludge process is distinctly higher in plant food values. Nitrogen may run as high as 6.0 per cent; phosphates may be present as high as 3.0 percent; but potash will be about the same as for other types of sludges. The higher fertilizer value has made further processing of the sludge possible where the final product could be disposed of in commercial channels. To be suitable for sale as commercial fertilizer, the moisture content of the sludge must be reduced to 10 percent or less. This is done by drying the sludge in rotary dryers as it comes from the vacuum filters. The dried product is then ground into a uniform size.

**Fresh sludge.** The sludge removed from sedimentation tanks is not always dried. Where sewage plants are near the sea or ocean, it is often

more economical to carry sludge, as it is drawn in an untreated condition from preliminary sedimentation tanks, in barges or steamers to sea than to provide extensive treatment. The disposal of sludge at sea is practiced in the United States at New York City, and at New Haven, Conn.; the Passaic Valley sewage treatment plant in New Jersey; at London and Manchester, England, and at several other places.

Large quantities of untreated sludge are discharged into lagoons or ponds around which earth embankments or dykes are constructed to retain the material. Lagoons of all sizes are in use, some covering several acres. In the course of time the sludge in them digests and becomes stable, or the sludge may be discharged at times of high water when there is adequate flow to permit disposal by dilution. Although the first cost of lagoons is small and they involve little if any expense to operate, they are generally considered an expedient. Odors are a frequent cause of complaint, and the accidental breaking of the retaining banks may result in serious stream pollution.

Fresh sludge is being used in some parts of the country, particularly those where rainfall is light necessitating irrigation practices. The sludge can be transported to the farm in tank trucks as at Marion, Ind., or if agricultural land is near enough, piped to the fields as was done at Canton, Ohio.

### Hygienic Aspects of Sludge Used as Fertilizer

Investigations have been conducted by numerous laboratories to determine any hazards connected with the use of sludge as fertilizer. Theoretically, there is a danger in the use of fresh sludge, either in a liquid state or as taken from the vacuum filters or sludge drying beds. Various enteric disease organisms and parasites have been found in sludge of this type, but illness has not been traced to the use of sewage sludge. (This statement does *not* apply to the use of fresh human wastes or "night soil".) Heat dried sludge is rendered safe by the heating process. Dried digested sludge is generally considered safe, also, particularly when used on grains, trees, etc.

Health departments have established rules for the use of sludge as fertilizer. The usual practice is to restrict fresh sludge to forage or grain crops. It should not be used on fruit or vegetables that are eaten raw and that form near the ground. It should be plowed under promptly after being spread. Heat dried sludge needs no special regulations. Although dried digested sludge has not been incriminated in the spread of intestinal diseases, the evidence is still inconclusive and even this sludge should not be used on vegetables and fruits grown near the ground and eaten raw.

## RURAL SEWAGE DISPOSAL

Areas in which the population density is light generally find that it is not economically feasible to have a common sewerage system or a sewage disposal plant. Individual residence sewage disposal systems are usual under these circumstances. The privy, cesspool, and septic tank with absorption field are commonly used. The United States Public Health Service has made an estimate of the number of homes using individual disposal methods as follows:[16]

| | | |
|---|---|---|
| Rural dwellings with outside toilet or privy | 8,515,572 | |
| No toilet or privy | 846,148 | |
| Septic tanks | 4,400,000 | |
| Other methods of disposal | 1,819,720 | |
| Total homes | | 14,581,440 |

On the basis of 4 persons per family, this represents a population of almost 60,000,000.

The above figures give an idea of the importance of proper facilities for those homes using individual disposal systems. Fortunately, in most instances where the privy or septic tank is used, the population density is such that liberal areas are available around houses for the installation of these crude facilities. This does not eliminate the possibility of public health hazards that may arise from improperly designed or operated disposal installations. The possibility of polluted water supplies is ever present, particularly in view of the fact that where individual disposal systems are used, private water supplies are usually used also. The improperly located septic tank or privy may pollute the poorly constructed well. The danger that exists from flies, especially when they have access to human wastes, is another hazard common to private disposal facilities. Supervision of private sewage disposal systems must be an important part of the environmental sanitation program of any health department covering a substantial rural or semi-rural population.

### General Principles

Reasons for the proper disposal of human wastes in urban areas have been given in the first part of this chapter. The same general concepts apply to waste disposal in rural areas although the concentration of the population, and so the quantity of wastes is usually such that direct health hazards are the chief concern of the health department. Those hazards have been previously referred to:

Pollution of water supplies.
Development of areas that may become fly-breeding areas, or
Possible sites for fly contamination with human wastes.
In particularly extreme situations, the danger of intestinal infestations from hookworm.

The goals to be attained in private disposal systems are simple. First, the wastes must be disposed of in such a way and in such locations that water supplies cannot be polluted, either by human wastes flowing over the surface of the ground into reservoirs or streams that become drinking water sources, or by seeping through fissures or cracks in the ground and to reach a well or spring. The second goal should be the prevention of fly-breeding or pollution of flies by their access to human wastes. Briefly, this means disposing of the wastes under ground or in other places that flies and other insects cannot reach. The danger of hookworm infestation can be eliminated by the use of any of the accepted methods of private sewage disposal to replace indiscriminate defecation on the ground.

Several types of disposal facilities, if properly constructed and operated, can give satisfactory and safe results.[22] The ordinary, earthen or concrete pit is the simplest, yet it can be safest. It is used where water-carriage sewage facilities are not available. When water is available in the home, making water-carriage sewage facilities possible, the septic tank is the best method of disposal. In some areas cesspools are permitted but they are generally frowned on by health officials for reasons that will be given later. Chemical toilets can also be used where water-carriage is not possible. In general construction these resemble the privy. Other methods are possible under primitive conditions approaching emergency situations or field conditions. These would be similar to those used by military units under field living conditions. The "straddle trench" serves as the type of waste disposal facilities that can be used under these crudest of arrangements.

## Pit Privy

Essentially the pit privy consists of an excavation in the ground with a cover which includes a seat of some sort. The secret of a satisfactory privy is its location in such a place that water supplies are not endangered, and construction of the pit in such a way that flies are excluded. From a hygienic viewpoint, there is no reason for a housing to enclose the seat. However, some privacy is usually desirable and in most parts of our country there are times of the year when protection from inclement weather is necessary. A sketch of a privy is given in Figure 63.

The privy should be at least 50 feet from any water supply. On the other hand, it should not be so far from the residence or working area that people will be discouraged from walking to it. A distance of about 150 feet is the maximum that should separate the privy from the home or business place. The size of the pit and its depth will depend upon the number of people to be served and the nature of the soil. The volume of the pit of a privy for the average-sized family should not be less than 50 cubic feet, and the distance from the front to the back of the pit should be about

3 feet. In many soils it is unnecessary to support the walls of the pit but in others some sort of cribbing may be necessary to prevent the soil from caving in and filling the pit. When cribbing is used, it should be not laid

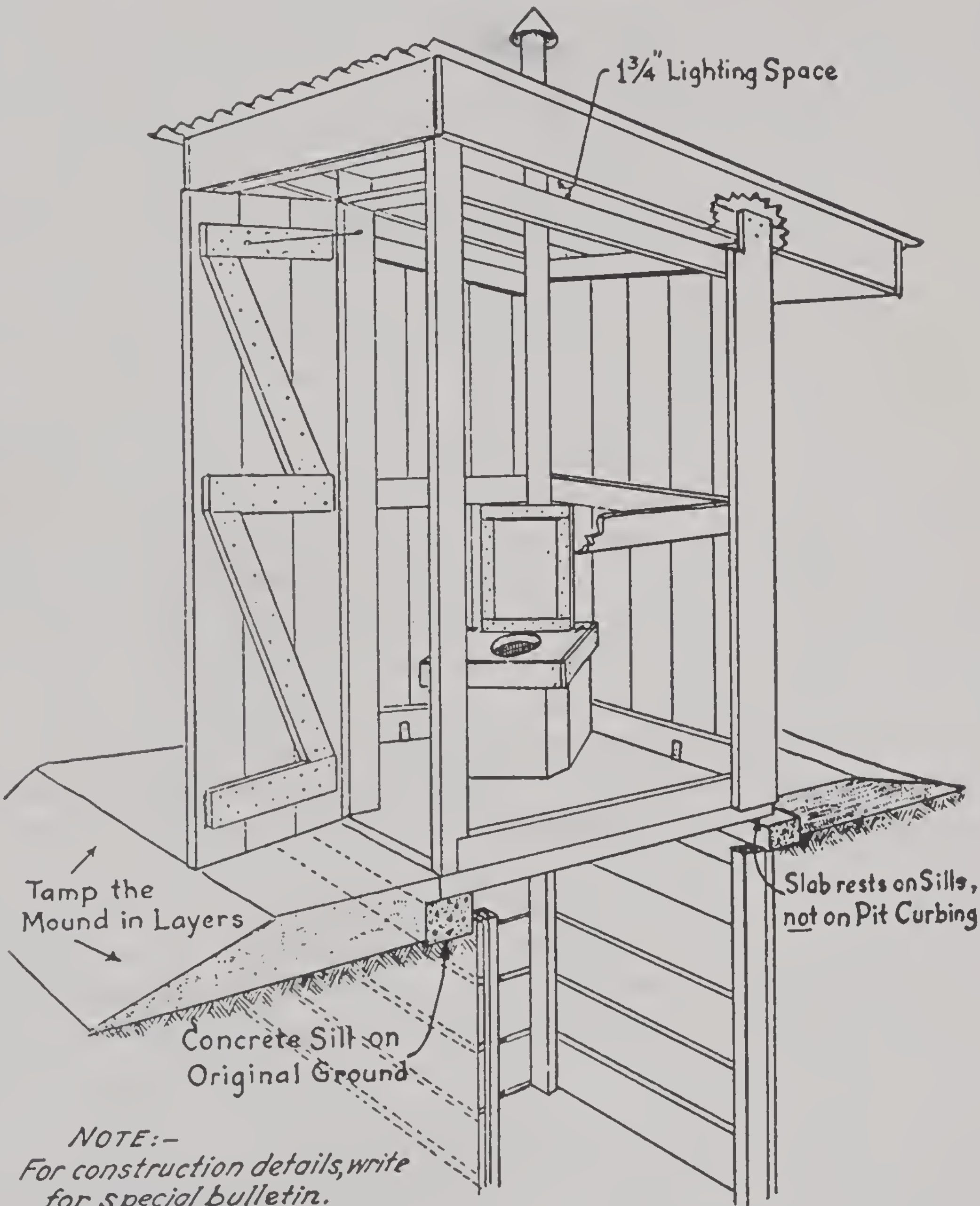


Fig. 63. Sketch of pit privy. (Courtesy, George L. Hall, Maryland Department of Health.)

tight but rather with openings between adjacent pieces of wood or cribbing material so that the liquids in the pit will seep out into the soil. Whenever the pit is dug below the usual level of water in the ground, that portion of the pit below water level is of very little value for the storage and digestion of wastes. A privy will not function satisfactorily in water-logged ground.

## Concrete Vault Privies

A concrete-lined pit or vault can be used with a privy. This construction prevents the seepage of liquids out of the pit as long as the concrete pit is

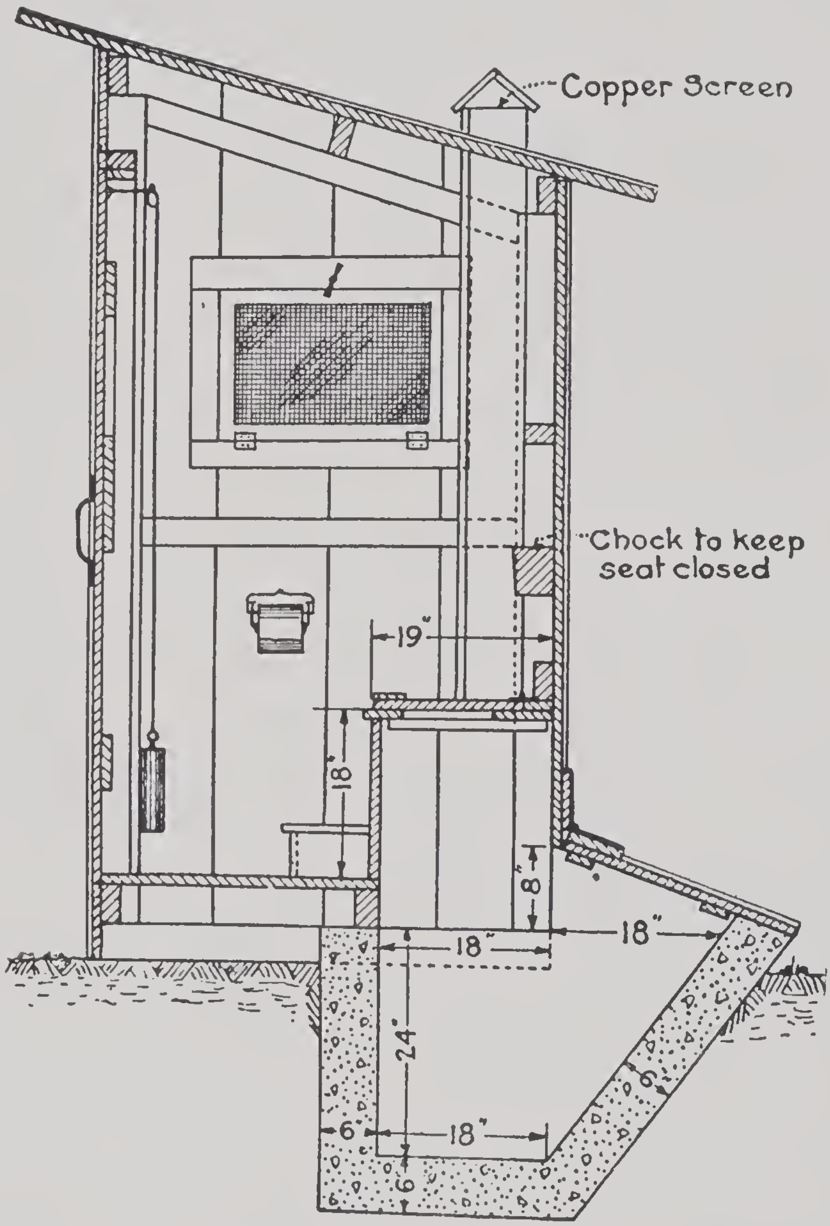


Fig. 64. Sketch of concrete vault privy. (Courtesy, George L. Hall, Maryland Department of Health.)

not cracked. It means that the solids and liquids must all be removed at regular intervals. Cleaning the pit of a privy is a dirty job at best and unless extreme care is exercised feces and urine cleaned from the pit may be dropped on the ground. Septic tank cleaners or scavengers can be hired in many rural areas for cleaning operations. The concrete pit, like the earthen pit privy, must be kept fly-tight.

## Pail or Can Type of Privies

Water-tight cans may be placed under seats of privies so that the feces and urine are collected in the containers. A privy of this type is frequently used in temporary installations as for construction gangs or at picnics or county fairs where permanent facilities are not available. Extreme care must be exercised in emptying and cleaning the cans. Sufficient clean cans must be on hand so that as the filled cans are removed a clean container can be placed under the seat immediately. Great care must be used to assure proper placing of the receptacle so that all of the urine and feces go into the can. A good practice is to attach stops to the floor of the area under the privy seat so that the receptacle can be placed in only one position. Contents of cans must be disposed of in a safe manner, either by burial or else by dumping in a sewerage system. The cans should be cleaned and sterilized immediately upon being emptied.

## Chemical Toilets

Some chemical toilets are similar to the concrete vault privy except that a metal tank is used instead of a concrete vault. Another type is similar to the pail or can privy. In either type a caustic solution is added to the receptacle to aid in the liquefying and decomposition of the feces. Sodium hydroxide is commonly used as the caustic agent. It is essential that the caustic solution and the fecal contents of the receptacle be kept in intimate contact. Some means must be provided for mixing the receptacle contents.

The chemical tank type usually has a bottom outlet so that the emulsified and digested solid matter can be discharged into a soakage pit of some sort where the liquids can seep out into the ground. It is also possible to clean out the tank by using the equipment of the septic tank scavenger. Care must be used to be sure that the caustic solution has been diluted sufficiently so that there is no danger to the persons emptying the tank or to the equipment used. The pails in chemical toilets using small receptacles are emptied into earth pits or the contents are buried otherwise. In either case, the pails must be washed and sterilized immediately after emptying. A fresh pail should be placed in the toilet as soon as the filled can is removed. The necessary charge of caustic solution should be added after the can has been put in place.

Chemical toilets are used in situations where it is desirable to have toilets indoors but where running water is not available for water-carriage toilets. These toilets are used frequently in those parts of the country where the outdoor temperatures get quite low. If the caustic charge is adequate and kept at proper strength the odors from chemical toilets should not be objectionable. If the caustic charge is not adequate or if it is allowed to drop down in strength because of excessive dilution or of decomposition

due to age, unpleasant odors will be produced. Good supervision is necessary for the satisfactory operation of chemical toilets.

## Septic Tanks

Septic tanks are used where water is available to carry the wastes from the toilets. The facilities inside the house are identical with those in houses

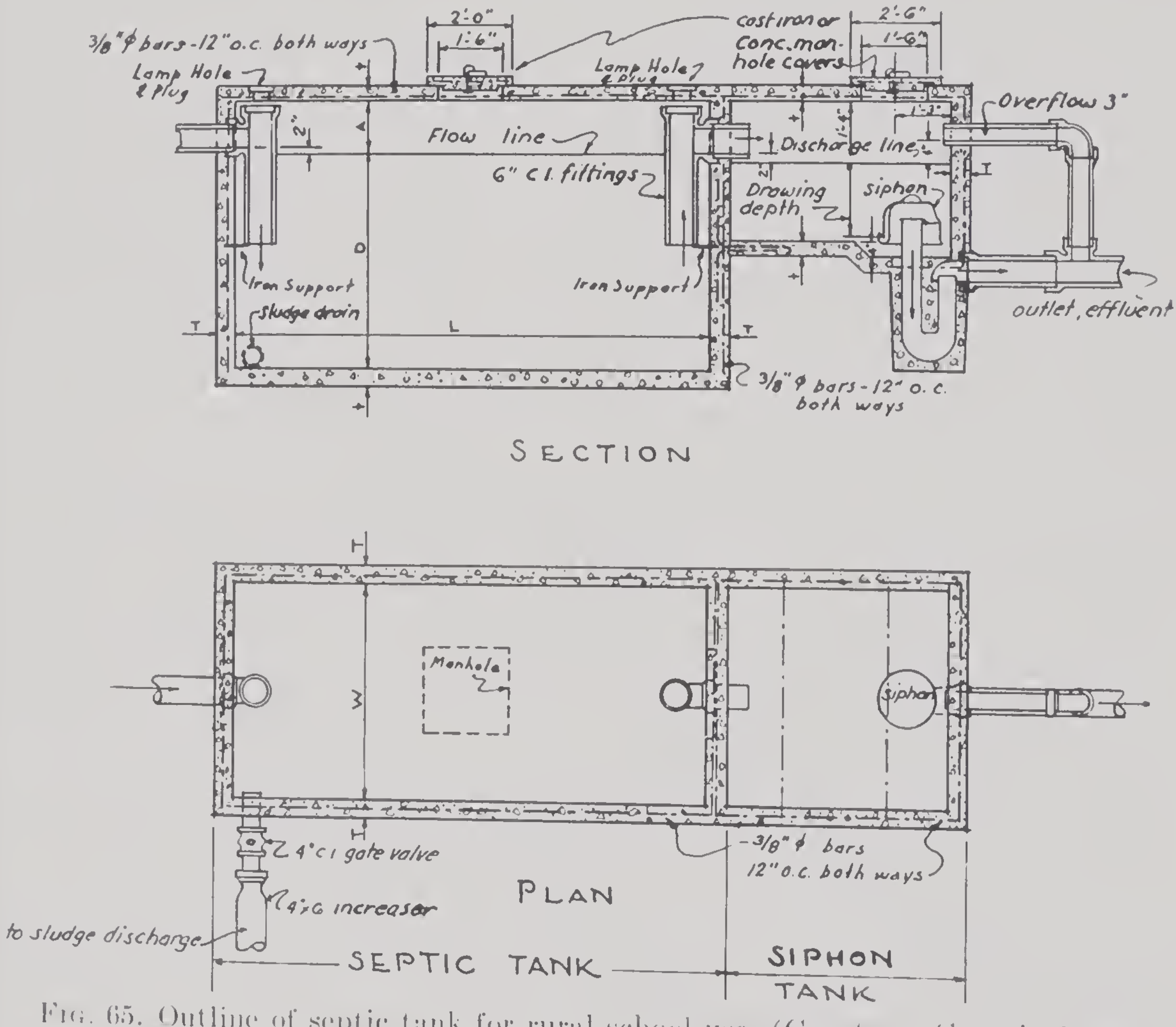


Fig. 65. Outline of septic tank for rural school use. (Courtesy, Georgia Department of Health.)

connected to a municipal sewerage system. The wastes are conducted from the house into a large tank so designed that solid matter has a chance to settle to the bottom of the tank where it eventually undergoes decomposition. The liquids flow out of the tank into buried tile lines so that the liquid wastes are disposed of by soakage into the ground. The solids must be removed periodically. Most of them will have undergone decomposition and digestion to the point where they will not be objectionable. A septic tank that is properly designed, installed, and operated should give satisfactory service for single families or large buildings.

The tank of a septic tank system serves as a sedimentation chamber and

a digestion tank. It must be designed and installed to give the maximum service in both operations. The tank must be large enough to permit retention of the sewage in the tank long enough to permit the solid matter to settle out of the liquids that flow through. The amount of sewage produced in 24 hours is generally taken as the size of the tank required by any building served by a septic tank. However, the minimum size of tank is 500 gallons. Average figures for the amount of sewage contributed under different circumstances are:[22]

50 gallons per capita daily in dwellings,
25 gallons per capita daily in camps, and
17 gallons per capita daily in day schools.

The tank should be made of material that will not readily rot or rust. Concrete has been found most satisfactory although heavily coated metal tanks are also offered for sale with the claim that they will not rust out quickly. Baffles are installed at each end of the tank—at the inlet end to disperse the liquids and spread the flow across the whole width of the tank and at the outlet end for the same purpose in addition to preventing scum from entering the tile lines. Submerged outlet connections can also be used at each end. Each tank should be provided with a cover strong enough to withstand any weight that may be put upon it. There should be at least one manhole to permit easy access to the tank for cleaning or repair operations. Various shapes can be used for the tank and there seems to be no reason why tanks with several compartments should not be used.[16] Tanks usually need cleaning about every 2 to 3 years.

The liquids from the tank should flow into a distribution box connected to the tank by a short length of tight sewer line. The purpose of the box is to provide some means for distributing the liquids evenly to all of the lines of tile used for the disposal of liquids. Good distribution is necessary if the maximum efficiency of the tile field is to be realized. If the septic tank is 1000 gallons or larger it will be found profitable to run the liquids from the tank into a dosing chamber with an automatic siphon. The use of this equipment means that the liquids will be stored in the dosing chamber until a fixed quantity is reached when the siphon will permit discharge of the liquids into the tile lines. An intermittent flow of liquids is thus obtained; this is desirable for percolation. The same action would be good for tile lines from smaller tanks but the cost of installing the chamber and siphon generally is large enough to overcome the advantages that would be obtained.

Grease traps are not considered essential in the septic tank system for a home. If large quantities of soapy water, as from a shower room, or if fats, as from a restaurant, are to be disposed of, a grease trap should be

installed. The purpose of a grease trap is to provide a short detention period for the sewage to permit it to cool off sufficiently so that the greases

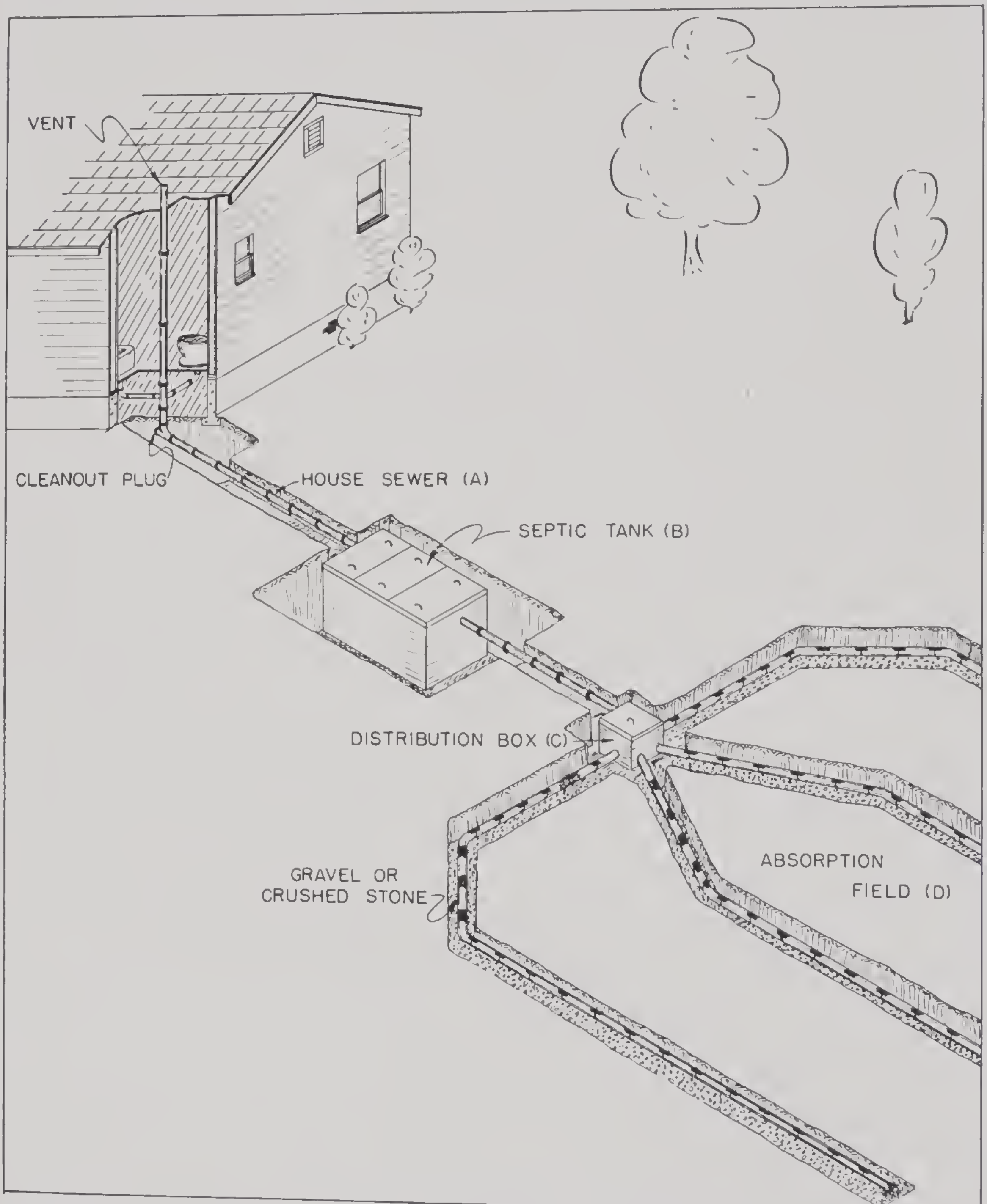


Fig. 66. Septic tank sewage disposal system. (Courtesy, John E. Kiker, Florida Engineering and Industrial Experiment Station.)

and fats in the liquids will rise and congeal at the surface. These greases and fats can be skimmed off and burned, buried, or sold. If allowed to flow through into the tile field they may clog the absorptive material around the tiles. Grease traps that are not kept clean will give off exceedingly objectionable odors.

The grease trap is connected to the house drain, between the house and the septic tank. The general construction is simple, consisting of a chamber, round or square, with a capacity of about 30 gallons for the average dwelling system. The inlet to the chamber should extend 6 inches below the surface of liquids in the trap, and the outlet should extend down to within about 6 inches of the bottom of the trap. The flow of water through the

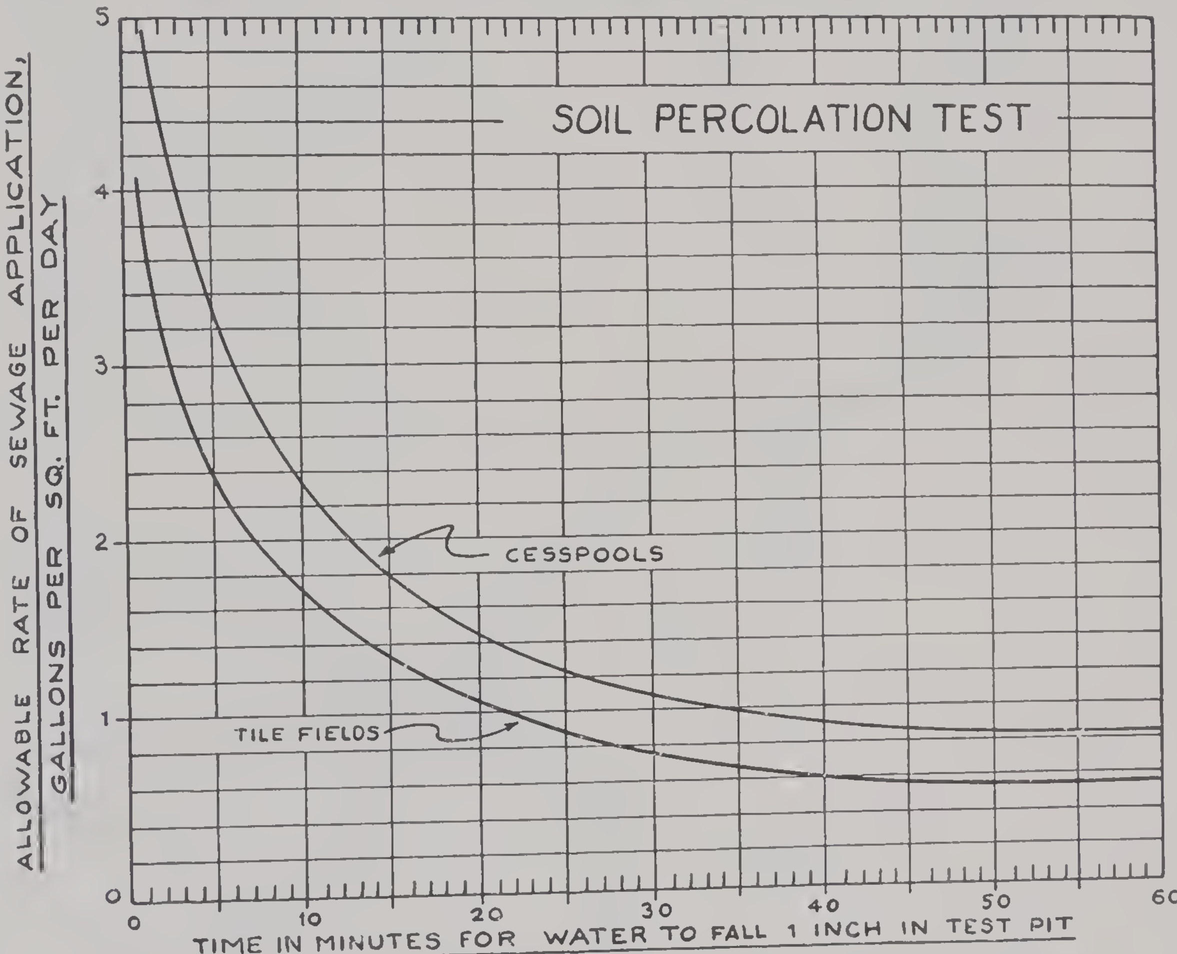


Fig. 67. Soil percolation curve for absorption of septic tank effluents

grease trap must be fast enough to prevent settling out of solid matter. Grease traps can be purchased commercially.

The tile line must be designed and installed with care. If the length of the lines is not sufficient, liquids are liable to appear at the surface of the ground. If the lines are not installed so that the grade to which they are laid is uniform and correct, portions of the lines may be cut out of use. All portions of the tile field should be at least 100 feet from the water supply well, 25 feet from any stream, and 10 feet from any building or property line. A distance of 50 feet to drilled wells is generally considered satisfactory provided the casing of the well is watertight for a depth of at least 50 feet.

Four inch agricultural tiles are generally used. They are laid in trenches with openings between the ends of adjacent pieces of tile. A space of $\frac{1}{4}$ to

$\frac{1}{2}$ inch should be left between tile lengths. The upper half of the opening should be covered with asphalt treated paper to prevent the entrance of dirt or pebbles into the pipe line when the trenches are being back filled. Trenches should be from 18 to 36 inches deep and 18 to 36 inches wide at the bottom. Care should be used in digging the trench to give an even grade to the bottom amounting to from 2 to 4 inches per 100 feet of trench length with the lower end away from the septic tank. If any portion of the tile line is to be in an area that might support vehicular traffic, vitrified tile should be used because of its greater strength.

The length of tile line depends upon the absorptive quality of the soil. In any case it is good to have the line divided into at least 2 lengths rather than having one extra long stretch of pipe. A length greater than 100 feet in one section should not be used. Adjacent tile lines should be separated from each other by at least 3 times the width of the trench bottom and at least 6 feet.

The amount of tile line depends upon the area of the bottom of the trenches used. The area needed is determined from an estimate of the quantity of liquids to be disposed of and the absorptive quality of the ground in which the trenches are dug. A percolation test is run to determine the rate of absorption. The test is performed by:

1. Digging a hole one foot square to the depth of the proposed disposal trench.
2. Pouring water into the hole to give a depth of at least 6 inches and then allowing the water to seep out of the hole. The depth of water should be measured and the time required for all of the water to seep out should be recorded. The time required for the water to drop one inch is obtained by dividing the depth of water in the hole originally by the length of time in minutes required for all of the water to run out. The effective absorption area required for the particular soil being examined can then be obtained from the following table:[22]

*Absorptive Area Required as Determined by Percolation Tests*

| Time required for water to fall 1 inch (in minutes) | Effective absorption area required in bottom of disposal trenches in square feet. | | |
|---|---|---|---|
| | Residences (per bedroom) | Camps (per person) | Schools (per person) |
| 2 or less | 50 | 13 | 9 |
| 3 | 60 | 15 | 10 |
| 4 | 70 | 18 | 12 |
| 5 | 80 | 20 | 13 |
| 10 | 100 | 24 | 18 |
| 15 | 130 | 32 | 21 |
| 30 | 180 | 45 | 30 |
| 60 | 240 | 60 | 40 |
| Over 60 | Special design using seepage pits or sand filter trenches. | | |

When the absorptive test is made some consideration should be given to unusual conditions of the soil at the time of the test. If conditions seem to be unusually dry, more than 6 inches of water should be added to the test hole. In no case should the test be made in filled or frozen ground.

The necessary length of the line must be laid with care. A layer of 6 inches of coarse absorptive material such as gravel, crushed stone, or slag should be spread over the bottom of the trench. The tile line should then be placed on top of the absorptive material and adjusted for grade and line and proper spacing. More of the coarse fill should be piled carefully around the tile so the tile is not pushed out of line. The top half of the joints is covered with tar paper and gravel, crushed rock or slag then piled around the tile line until a covering of at least 2 inches is obtained. The trench can then be filled the rest of the way with dirt.

Sand filter beds are sometimes used in areas where the ground is waterlogged much of the time. The septic tank effluent is admitted to the top portions of the filter bed and the filtered effluent collected in pipes laid below the sand bed. A layer of sand about 30 inches deep is laid on a layer of graded gravel about 6 inches deep. The collection pipes are laid in this layer of gravel. About 32 square feet of filter area per person served is required. The effluent from the sand bed in most cases will be suitable for discharge directly into some body of water not used for drinking purposes.

The primary purpose of a septic tank is to dispose of wastes that have definite public health importance. The design of the tank and of the tile field should provide a system large enough to give adequate treatment. Treatment in this system of rainwater, laundry water, and other liquid wastes that do not have the full hygienic significance that human wastes have is uneconomical. Rainwater from roof gutters should be run into separate soakage pits and not into the septic tank. Laundry wastes, if separate disposal is possible, can profitably be run into a separate soakage pit or tile line system, particularly if the volume is large. Laundry wastes should be disposed of beneath the surface of the ground because they can provide mosquito breeding ponds that will be prolific producers of pest mosquitoes if the liquids are allowed to flow out on the ground surface.

## Cesspools

These are excavations from 4 feet in diameter to almost any size and from 6 to 8 or 10 feet deep. The walls of the excavation are lined with stones, cinder block, or any other suitable material that will hold the dirt back but permit liquids from the cesspool to soak out.

The liquids from a water-carriage sewage system are conducted directly to a cesspool for disposal. In sandy gravelly soil cesspools may prove satisfactory, but in most areas they are considered undesirable because

the depth of excavation frequently is such that the cesspool contents are carried down into the water table. Adjacent water supplies may become polluted by cesspool seepage into ground water.

A septic tank is better than a cesspool from a hygienic standpoint. When properly constructed and operated septic tanks, including adequate tile fields, prove much more satisfactory from an operating viewpoint also. Use of cesspools should be discouraged even in those areas where they are permitted.

### Other Methods of Disposal

Various other methods of sewage disposal in rural areas or in areas that are not served by a municipal sewerage system are in use. In general they reflect conditions peculiar to the area. Bored-hole privies have found extensive use in some situations. Incineration is used in some areas where other, simpler methods are not suitable. In emergencies, when materials or time do not permit construction of more elaborate facilities, the straddle trench that was used so often by military units on the move is a satisfactory method.

Any public health staff member may be called upon to provide some satisfactory method for sewage disposal other than into a municipal sewerage system. Many methods can be used and any one of them should be satisfactory if the reasons for sewage disposal are considered. These reasons for the public health worker are:

1. Protection of water supplies—both private supplies and those that may become part of a municipal system.
2. Prevention of accumulations that will serve as fly-breeding sites or that will provide means for pollution of flies with human excreta.
3. Prevention of the fouling of the surface of the earth in the interests of intestinal parasites control.
4. Under some circumstances, prevention of accumulations that might serve as mosquito breeding nuisances.

## CONCLUSIONS

Next to a water supply system, a sewerage system is the most essential public improvement in a city. The installation of sewerage systems and treatment works has undoubtedly had considerable bearing on the great decrease in typhoid fever during the past 40 years. Where adequate sewage works are provided and properly operated, the diluting waters, into which effluents discharge, may be expected to be free of unsightly sewage solids; fish life will be maintained; the use of the water at recreational centers may be continued with safety; and water supplies will be protected. The happiness and health of many people are dependent upon the proper maintenance and operation of municipal sewerage systems.

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Chapter VIII

# THE CONTROL OF STREAM POLLUTION

Stream pollution for present purposes may be defined as the creation of objectionable conditions through the discharge of sewage and trade wastes into natural water-courses. These objectionable conditions cover a wide range of situations, varying in importance from water-borne disease hazards to minor esthetic considerations.

## EFFECTS OF POLLUTION

The injurious effects of pollution, particularly during the past several decades, have become increasingly apparent in the United States with the growth of large cities and the rapid expansion of industrial activities. In general, the increase in pollution in the past has far exceeded the reductions that have been made through sewage and waste treatment. Hazards to health and welfare, with foul conditions existing along many streams, have resulted. It is estimated that the inland waterways of this country receive a volume of raw domestic sewage equivalent to that of 47 million people and an industrial waste load equivalent to the raw sewage of 60 million persons.[1] The trend of events in recent years, however, presages a change for the better. There is evidence of a growing appreciation of the necessity of preventive and corrective actions. The Ohio River which has been under study for many years by the United States Public Health Service through its station at Cincinnati, Ohio, serves as an example of the magnitude of the problem. In 1943 a comprehensive survey of the river was authorized by Congress at a cost of $600,000. This investigation disclosed multiple use of the river including domestic water supply; sewage and waste disposal; recreation; navigation; and power production. The average flow at Pittsburgh, Pa., was 4900 cubic feet per second; at Paducah, Ky., 47,100 cubic feet. It furnished water for 30 supplies of water for 1,660,000 people. The domestic sewage pollution was equivalent to 6,396,400 people, and industrial wastes to 9,071,700 people with acid wastes equal to 1,864,800 tons per year. Remedial action, including mine sealing, to remove 50 percent of the suspended solids and 35 percent of the B.O.D. from all sewage and industrial wastes, will cost $200,000,000.[10]

## PUBLIC HEALTH IMPORTANCE

Pollution of waterways may directly affect the public health where the water is used as a source of public water supply, for the propagation of oysters or shellfish, for ice supply, or for bathing purposes. The records of

water-carried disease epidemics, due to sewage pollution, are all too familiar to need repetition.

Probably the most important protection against widespread epidemics of typhoid fever and other gastro-enteritis diseases caused by drinking polluted water has been afforded by modern water purification systems. There are limits to the amount of pollution that can be handled by even the best purification systems, if a safe supply is to be consistently maintained. In some cases, cities have been forced to develop new sources of public water supply because of excessive pollution by sewage and wastes.

Pollution from industrial wastes usually does not constitute a serious menace to public health unless it interferes with the normal process of purification where the water is used as a public supply. Exceptions may include those wastes containing toxic substances or organic wastes, the decomposition products of which are intestinal irritants. Indirect influence on public health may be experienced through the toxic effect of some industrial wastes on sewage disposal methods.

Dangers to public health lurking in grossly polluted sources of public water supply are illustrated by an epidemic of intestinal disorders occurring at Charleston, W. Va., during 1930. Although unusually careful water purification methods were employed to remove the turbidity and *B. coli* organisms, with the supply presumably meeting accepted bacteriological requirements for a safe water supply, a nauseating taste and odor caused by industrial and domestic pollution prevailed after treatment. Only by boiling the water for several minutes could the tastes and odors be removed.

A careful study of this epidemic by the U. S. Public Health Service indicated that a chemical gastro-intestinal irritant was probably the cause of illness. The fact that the same ailment made its appearance successively in at least six widely separated cities along the Ohio River below the mouth of the Kanawha, all using the river as a common source of water supply, led Veldee[29] to conclude:

> "The evidence strongly suggests that the acute gastro-intestinal symptoms were brought about by the presence in the water of some chemical irritant whose physiological action simulated a strong purgative. The evidence does not show whether this chemical irritant was a cleavage product of bacterial action, a new chemical produced by bacterial synthesis, or the result of increased chemical concentration in the water brought about by a decrease in the diluent. There is at least a slight suggestion from the evidence that the toxic substance originated in the Great Kanawha River and was released into the Ohio when the dams were lowered on the Great Kanawha late in December, thereby releasing the pent-up wastes in a concentrated form which affected the public supply of each city as it moved down stream."

It is generally recognized that the most important use of a stream is as

a source of public water supply. Any pollution which interferes perceptibly with the quality, or potability, of the water furnished the consumer, such as that occasioned by trade wastes containing phenols, tarry acids, and similar compounds is objectionable. Salty tastes have been occasioned by brine wastes from oil fields. These various tastes and odors have frequently provoked the water users to obtain drinking water from sources of unknown or questionable purity, which has resulted in some instances in severe outbreaks of water-borne diseases.

The marked increase in the use of lakes, streams and tidal waters for recreational purposes in recent years, including bathing, boating, and fishing, has directed attention to serious pollution conditions. Through such recreational activities persons come in more or less intimate contact with polluted waters. There are health hazards involved in such contact, particularly in areas in proximity to sewer outlets where raw sewage and deposits of sludge are encountered. Actual epidemiological evidence of illness transmitted by swimming, fishing, or boating in polluted water is scant. However, in addition to enteric diseases, eye, ear, nose, and throat infections and skin irritations might be considered illnesses that could be related to polluted waters. A report from Japan tells of an infestation of hookworm traced to heavily polluted water in which the boy infected waded.[52] Tidal action, temperature, and wind currents, contamination introduced by bathers themselves and the different types of sewage pollution all have an influence on the hazards in the waters used for recreational purposes which also receive sewage and industrial wastes.

The direct effect of waste pollution upon fish life may be due to reduction of the dissolved oxygen of the stream to such an extent that the fish suffocate, or the wastes may be directly toxic. The former condition, however, is the most common cause of the death of large numbers of fish since relatively few trade wastes are present in most streams in quantities sufficient to produce poisoning. The wastes may use up the dissolved oxygen of the stream by direct chemical reaction, but usually depletion is caused by oxidation through biological agencies. If the oxygen demand of a waste discharged into a stream exceeds, or even approaches, the amount of oxygen available in the stream the resulting depletion will cause the death or migration of fish.

Investigations made of pollution in the Illinois River, and data presented by the Bureau of Fisheries, U. S. Department of Commerce,[14] indicate that if the dissolved oxygen content of the water falls below two parts per million, fish will probably suffocate or migrate.

Many authorities indicate that the dissolved oxygen content for best results in fish propagation should be kept at a materially higher amount than two parts per million. There is a marked difference between the oxy-

gen requirements of the various kinds of fish. The maintenance of three or four parts per million or more of oxygen may prove essential in waters used primarily for fish culture.

Temperature has definite effect on the ability of a stream to support aquatic life. In winter, ice coverage materially retards atmospheric reaeration. During warm weather, decomposition of the organic matter is very rapid and the oxygen of the stream is used up more quickly. On the other hand the amount of oxygen that fresh water will actually retain in solution is less in warm than in cold weather, being about 9 ppm. at 68° F. and 14 ppm. at 32° F.; so that in warm weather when a greater supply of oxygen is required by the pollutional wastes, less is available in the stream. Furthermore, the tolerance of fish for toxic wastes is greater in a cold than in a warm water, but a greater amount of oxygen is required by the fish when the water is warm. Warm weather, therefore, is apparently deleterious to fish life in many ways.

Water with high turbidities, such as 6,000 ppm. will at times kill fish if the suspended mud reduces the dissolved oxygen below 2 ppm. Game fish such as trout require at least 5 ppm. of dissolved oxygen to survive indefinitely. Heavy mud will also prevent re-oxygenation and kill fish spawn.[16]

This discussion in regard to dissolved oxygen refers specifically to the effect on adult fish. The indirect effect due to changes of natural conditions appears to be undetermined but is probably a material factor. Fiber and other sludge settling over the spawning beds of fish cause them to seek other spawning grounds or prevent the natural development of the spawn. Furthermore the most susceptible period of young fish life is just after the food sac is absorbed, since the fish are sustained by this food sac from the time of hatching until it is used up. The fish must then depend upon natural aquatic life for sustenance. Studies have indicated that eggs taken from pike in polluted water could not be successfully hatched in the same water but had to be transferred to cleaner water. It appears that pollution has a much more deleterious effect upon eggs and young fish than upon the adult fish. The actual interference of pollution in fish propagation, therefore, may be much greater than is indicated by the reduction of the dissolved oxygen of the stream to below two parts per million.

## EFFECT ON WATER FOWL AND OTHER ANIMAL LIFE

Sportsmen and conservationists have not only called attention to the deleterious effect of pollution on fish, but have shown that water fowl and other animal life have suffered. An investigation to determine the causative factor in the death of hundreds of mallard ducks, snipe and mud hens in a polluted locality indicated that death of the wild fowl was

due to poisoning by *B. botulinus* presumably originating from sewage and sludge deposits exposed through dredging operations in the feeding area.

There are some trade wastes which have caused injury to animals drinking water containing sufficient amounts of the waste to exert direct toxic effects. A considerable number of cases have been reported, such as cyanide poisoning of live stock.[32] These conditions are observed with domestic animals but usually pass unnoticed as far as wild life is concerned.

Aside from toxic effects, dairy cattle may drink water containing pollutional wastes that give a flavor to the milk. This was illustrated in the effect of a stream that was polluted by kraut canning wastes flowing through grazing lands.[30] During the canning season the milk acquired a kraut flavor which materially interfered with its marketing. Another consideration in dairying is the contact of sewage pollution with udders of cows wading in streams, with the possibility of serious bacterial contamination of the milk should there be a lack of adequate safeguards in milking operations.

There are many other considerations, but no adequate survey has been made to determine the extent of damage by pollution inimical to aquatic and other animal life. The facts that may be obtained by such surveys are necessary in the development of a justifiable corrective and control program.

## EFFECT ON PLANT LIFE

When nitrogenous organic wastes are discharged into a stream, decomposition takes place as explained on page 205 with the resultant formation of nitrates, a plant food. Should the decomposition be so rapid that it completely consumes the oxygen of the stream, anaerobic or septic conditions will prevail. Under these conditions the plant life in the water course changes entirely, green plants and other classes of aerobic life die and anaerobic organisms (worms and lower animal life particularly) prevail in the bottom sediment. Since flowing water dissolves more oxygen from the atmosphere, nitrification will proceed continually and a surplus of dissolved oxygen may ultimately be available. Because of the fertilizer value of the nitrates, plant life further down the stream may become more than normally luxuriant.

A luxuriant vegetation may have a very material effect upon the condition of a stream and aquatic life. Growing plants give off oxygen under the influence of sunlight and furnish food for fish and other aquatic life. On the other hand, oxygen is consumed when dead plants decay. In the summer or growing period, therefore, plant life may be beneficial, but in the late fall or winter, while decay occurs, it is detrimental to fish life. This is

probably an important factor in the cause of dead fish during the winter months when lakes are covered with a sheet of ice, since it is during this period that decomposition of the vegetation uses up the oxygen and the ice sheet prevents sufficient reaeration of the water to meet requirements. Vegetation or plant life is essential for fish life. It has been aptly stated, "no plankton or vegetation, no fish."

## ECONOMIC FACTORS

Many considerations enter into the economic aspects of stream pollution. Agricultural, commercial, industrial and other interests are affected in varying degree by water pollution. Harmful pollution in relation to dairy-farming has already been mentioned. Aside from stock raising there may be damage occasioned in the use of waters for irrigation. Some trade wastes are reported to be detrimental to crops, but domestic sewage would normally prove beneficial because of the fertilizing value. The possibility of transmitting disease raises a serious question as to the advisability of using sewage polluted waters for irrigation of crops that are to be consumed uncooked.

Pollution resulting in the deposition of sludge which creates shoals in stream beds may interfere with navigation and increase the necessity for frequent dredging to maintain navigable channels. Deposits resulting from quarrying and mining operations usually contain rapidly settling materials.

In many instances the shoaling of navigable waters is appreciably affected by solids from sewage and industrial wastes. There is also damage to vessels, locks, dams and other facilities of water transportation through accelerated deterioration caused in some instances by acid pickling liquors, mine drainage and other acid types of pollution.

Manufacturing processes often need water supplies free from the impurities that unrestricted pollution may introduce. Objectionable color, turbidity, and dissolved impurities of both organic and inorganic nature have materially interfered with industries, frequently necessitating considerable expense for water treatment or the development of new supplies. Acid drainage and some chemical wastes will cause very rapid deterioration in boiler plants.

Evaluation of damages caused by pollution is not easy, but can be accomplished with a sufficient degree of accuracy for all practical purposes. The methods employed by Black and Vaile[41] are enlightening in this respect. Depreciation in property values due to offensive conditions created by pollution, such as sludge deposits, sewage sleck and scum, can be approximated. Decrease in land value is in a sense a measure of the esthetic considerations involved.

FIG. 68. Pollution in the lower Schuylkill River. (Courtesy, Interstate Commission on the Delaware River Basin.)

## CRITERIA OF STREAM POLLUTION

The biochemical oxygen demand (B.O.D.) is the quantity of oxygen required for the biochemical oxidation of organic matter and is expressed in pounds of oxygen. The standard laboratory test for B.O.D. measures to 68 percent of the total demand. This standard indicates a per capita contri-

bution of B.O.D. through sewage of 0.17 to 0.18 pounds per day. The biochemical oxygen demand and dissolved oxygen tests are generally regarded as being of major importance in pollution surveys. The B.O.D. is used to evaluate the pollutional character of a waste, either before or after dilution in a stream.

A stream receiving industrial and domestic waste carries suspended particles which settle out, forming mats of deposited material on the stream bottom. The soluble and suspended pollution carried by the stream is indicated by the B.O.D. and concentration of dissolved oxygen. The deposited material becomes septic and slowly digests, just as sewage sludge does, with the decomposition products, both gaseous and colloidal, diffusing to the water layer above the bottom. It is not unusual to find stream bed deposits with B.O.D. demands greatly in excess of the water above them and to find them undergoing anaerobic fermentation.[22]

The capacity of a stream to receive and oxidize wastes depends upon oxygen resources which consist of the dissolved oxygen normally present in the water, the oxygen taken up by the water in reaeration, and that supplied by nitrates and plant life. As the oxygen content of a stream is depleted the tendency to absorb oxygen from the atmosphere becomes greater.

When the total oxygen requirements of decomposing organic matter in a water exceed the amount of dissolved oxygen available from that water there is said to exist a "negative oxygen balance." Such water would putrefy if the rate of reaeration were insufficient to supply the deficit. The oxygen determination, therefore, demonstrates actual and potential nuisances in a stream survey. Interpretation of results in terms of control measures is not always easy, since should there be several sources of pollution tributary to a stream, the responsibility for objectionable conditions as they relate to any specific pollutional contribution may be very difficult to establish.

Although relative, since it is affected by time factors, the oxygen balance may be expressed in terms of population capacity. It is the best measure of biological conditions. As an example, little oxygen is needed to overcome pollution for a day but a large amount is necessary for 10 days. Lower excess oxygen will be satisfactory in a short stream with large dilution, as compared to that needed for a large stream with little reaeration.

Streams restore their oxygen balance by reabsorption of atmospheric oxygen from surface agitation, by algae and bacterial metabolism. Flow ratios commonly used to estimate the amount of sewage assimilated vary in accordance with the physical ability of the stream to regain its oxygen balance. With swift flowing streams, volumes of flow above 3.5 cubic feet second per 1000 population have been considered adequate to avoid nui-

sance. The Chicago Drainage Canal, designed upon the basis of 3.33 cubic feet second per 1000 population is grossly polluted due to its sluggish flow and high organic load. In 1910 sewage in New York harbor was estimated to be diluted corresponding to 10 cubic feet second per 1000 population, yet due to the absence of sufficient new water and tidal action, the harbor was grossly polluted.[22]

## STANDARDS OF CLEANLINESS

Standards for pollution control must be established to fit local needs.

> "Rivers attract population and population demands disposal of sewage as well as water supply. On some industrial rivers the proportion of pollution would so hamper industry that the manufacturer would be forced to go out of business or move away; consequently, many rivers must be used for manufacturing, drainage, and water supply, others may become unfit for water supply and be relegated to drainage and manufacturing uses only. However, streams, in other words, must be used for the best interest of all riparian owners and with due regard of the rights and convenience to all."[33]

Attempts to formulate adequate standards of cleanliness of waterways for general application are known to extend back at least to the activities of the Royal Commissions on River Pollution in England, described in reports of the First Commission in 1865, and the Second Commission in 1868, along with reports of succeeding Commissions between 1870 and 1875. In the United States attention was first given to this phase of the general problem of waterways sanitation when, in 1872, the Massachusetts Board of Health began a study of sewage disposal and stream pollution in that state, leading to the well-known series of investigations at the Lawrence Experiment Station.

The earlier standards, such as set forth in the reports of the British Royal Commissions and as formulated later by Hering,[11] Stearns,[24] Hazen,[10] Goodnough[6] and others, in specifying the number of cubic feet per second of stream flow required for the inoffensive disposal of sewage contributed per 1,000 population, had as their primary purpose the prevention of nuisances rather than the safeguarding of public water supplies. Developments in recent years have led to the establishment of limiting degrees of water degradation, governed by the accepted uses of the waterways, and defined in units of readily determinable physical, chemical, biological, and bacteriological qualities of the waters.

The Ohio River Valley Water Sanitation Commission in 1949 established as a standard for the Cincinnati pool on that river, between the Little Miami River and Dam 37, some 22.3 miles downstream, the complete removal of settleable solids and a 65 percent reduction of the B.O.D. for organic wastes discharged into the pool, with additional treatment of wastes to assure not less than 4 ppm. of dissolved oxygen below Cincinnati.

Standards established by the Potomac River Interstate Commission require that the Class A portion of the river be usable after chlorination as a public supply; that Class B is fit for recreation and fish life; that Class C is usable as a source for public water supplies after complete treatment while Class D may border on being a nuisance.[47] No portion of this river has been designated as Class A.

Minimum standards for the Delaware River Basin are based upon the characteristics of the wastes discharged into the river and not upon water quality.[43] The river is zoned into four classes. Wastes discharged into the areas usable directly for water supply shall be free of turbidity; shall not exceed a B.O.D. of 50 ppm.; and their coliform organism density shall not be greater than 1 per ml. in more than 25 percent of the samples tested. In areas reserved for water supply after purification, wastes shall not be discharged within 2 miles of a water intake, and shall not deplete the dissolved oxygen below 50 percent saturation.

Standards adopted for the Ohio River are shown in Table 16. These have been generally accepted as usable criteria to reduce pollution in the major rivers of this country. Standards of pollutional limitation to apply to agricultural uses have been established in some states. Colorado requires that waters used for irrigation of edible vegetable crops contain no more than 1,000 Coli-Aerogenes bacteria per 100 cc. No quality requirements have been developed for streams used for stock watering, although Maryland requires chlorination of all sewage entering such streams. Some states bar cattle from irrigation ditches which receive sewage.

The use of plankton as a measure for stream pollution is being advocated.[17, 21] It is believed that species identification may be good evidence as to the cleanliness or degree of pollution of a stream. Based upon the assumption that undesirable pollution destroys the normal flora and fauna in streams, direct examination of the density of various species will make possible a classification of waters in relation to pollutional severity.

In general, harmful effects of pollution pertaining to stream uses must be properly evaluated and limits defined in suitable physical, chemical, biological, and bacteriological units. The relation of one to the other of the various units must be thoroughly established. This is essential to intelligent application of any general standards to waterways having more than one major use.

Only through the cooperation and careful coordination of studies conducted by sanitary engineers, laboratory workers, epidemiologists, fish culturists, and others will it be possible to make satisfactory progress toward the establishment on a firm scientific foundation of acceptable standards of cleanliness for lakes, streams, and tidal waters.

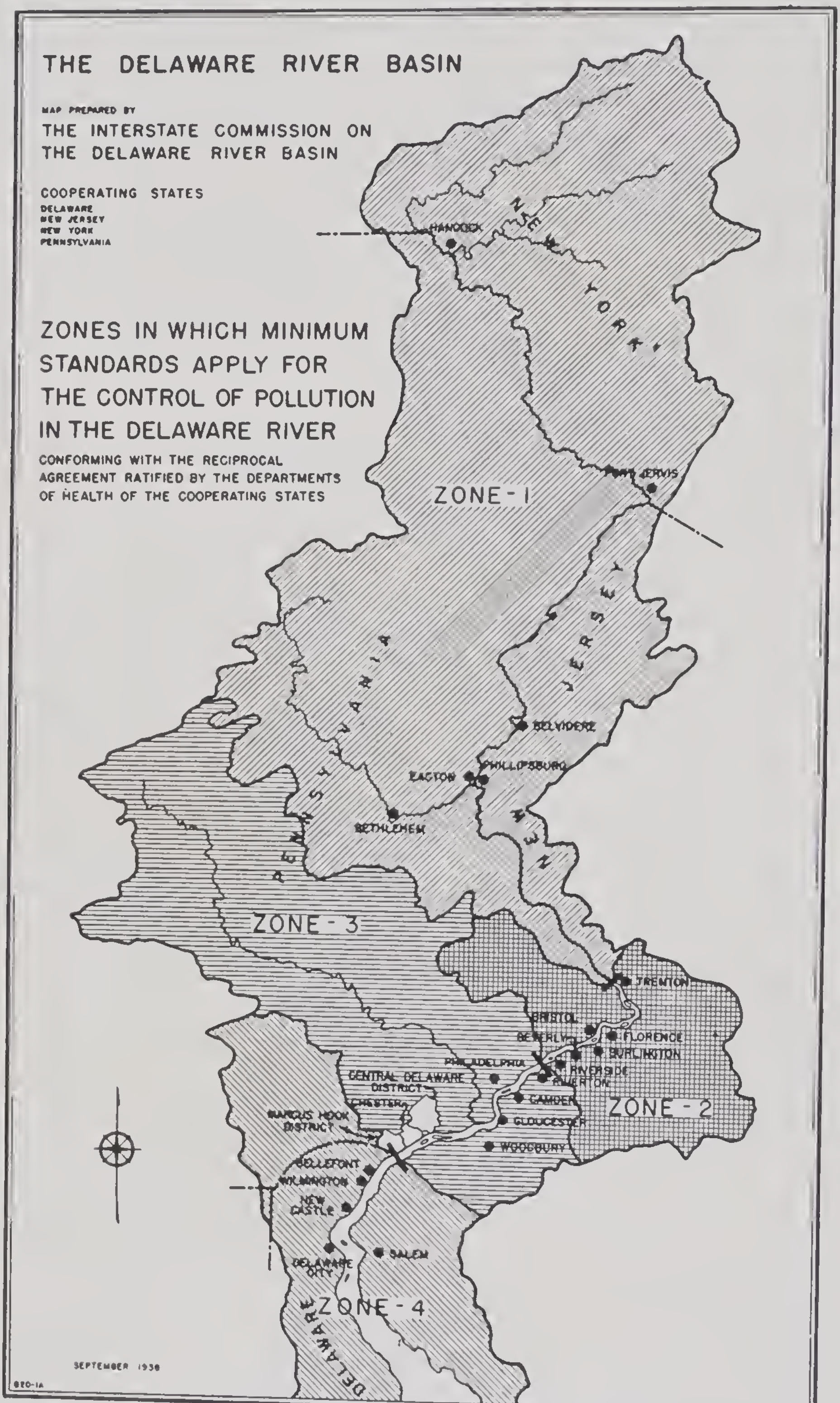


FIG. 69. Zone system of river pollution control. (Courtesy, Interstate Commission on the Delaware River Basin.)

## ADMINISTRATIVE PRACTICE

Riparian rights are a basic factor in stream pollution control. The right to secure water from a river is acquired by the purchase of the land adja-

TABLE 16

*Water Quality Characteristics, Ohio River Basin*

| Characteristic | Occurrence | Desirable | Doubtful | Unsuitable |
|---|---|---|---|---|
| | | Water Supply—General sanitary conditions | | |
| Coliform bacteria per milliliter | Average | Not over 50 in any month (filtration treatment required if over 0.5) | 50–200 in month unsuitable if greater than 200 in more than 5% of samples | Over 200 in any month |
| | | Bathing—Recreation | | |
| Coliform bacteria per milliliter | Average<br>Maximum | Not over 1.0<br>Not over 10.0 | 1.0–10.0 | Over 10.0 |
| | | Fish life—Recreation—General sanitary conditions | | |
| Dissolved oxygen parts per million | Average | Not less than 6.5 in any month | 5.0–6.5 in any month | Less than 5.0 in any month |
| | Minimum | Not less than 5.0 on any day | 3.0–5.0 on any day | Less than 3.0 on any day |
| | | General Sanitary Conditions—Recreation | | |
| 5-day. 20°C. biochemical oxygen demand, parts per million | Average | Not over 3.0 in any month | 3.0–5.0 in any month | Over 5.0 in any month |
| | | Water supply—Fish life—Recreation—Navigation—Industry | | |
| pH | | 6.5–8.6 | 4.0–6.5 or 8.6–9.5 (suitable for water supply prior to treatment) | Less than 4.0 or over 9.5 (unfavorable for water supply prior to treatment) |
| | | Fish life—Recreation—General sanitary conditions | | |
| Sludge deposits | | No preventable deposits present | Slight to moderate—localized | Moderate to heavy—general |

Ohio River Control, 78th Congress, House Docu., No. 266, part 1, p. 25, 1944.

cent to it. These rights originated in the common law of England and are recognized as assets inherent to the land.[20]

"The basic rule of the common law has been stated to be that each ri-

parian proprietor has the right to have the stream come down to him with its quality unimpaired and its quantity undiminished." This decision, rendered in the case of Younker v. Sankier Distillery Co. et al.,[38] has been a guiding principle in many subsequent court cases, both in England and America.

In the arid western portion of the United States a new procedure, the doctrine of prior appropriation, has been established. Under this policy riparian rights are not inherent assets of the adjoining land but economic use may be made of water for a given purpose subject to the rights of others. This diversion and use may be continued as long as needed, if the water is used for the purpose for which it was appropriated. Non-use for a certain period will usually cause a loss of these rights. This doctrine is the outgrowth of customs established during the mining booms of the last century in this western territory and resolves itself into the need of the user and his priority claim to use.

In recent decisions the United States Supreme Court has affirmed the common right of riparian ownership as to private persons but supported the doctrine of equitable appropriation of interstate streams between the states through which they flow.[18]

The control of stream pollution is a function of state government and regulation of interstate streams beyond local problems may be secured through interstate compacts. Although, as will be discussed later, a federal stream pollution law operating through the states has been implemented, it should be noted that the powers delegated to Congress by the commerce clause of the Constitution are limited and do not authorize pollution control by a federal agency, except to fulfill international treaty obligations.

In the United States, early legislation looking toward correcting pollution conditions was enacted in Massachusetts. In 1872 the first important investigation was authorized, and this was carried out by the State Board of Health. The precedent established would appear to have influenced legislation in other states, as many subsequent laws for pollution control have designated boards of health as the administering agencies. Conservation or game and fish departments, public service commissions, and other state agencies have been called upon to administer certain phases of pollution control.

## Federal Control Activities

In 1893 Congress authorized the United States Public Health Service to cooperate with state and municipal boards of health in the execution and enforcement of the rules and regulations of such boards; and further, in 1912[36, 37] authorized studies and investigations either directly or indirectly of navigable streams and lakes of the country. The Public Health Service

has accordingly extended assistance to states making pollution surveys, in carrying out water, sewage, and trade wastes treatment studies, and in conducting other important activities.

The Oil Pollution Act of 1924, administered by the United States Army Corps of Engineers, and earlier rivers and harbors acts, protect navigable waters from the discharge of oil and solids which would interfere with navigation.[39] The New River decision[2, 9] by which any stream capable of supporting a row boat is navigable, extends oil pollution control over wide areas.

## State Compacts

Present day trends of legislation toward usage and control of the large interstate rivers are leading to compacts between the interested states, although a federal stream pollution control law has been enacted. These agreements, based upon the drainage area of the river, may be formal treaties ratified by The Congress of the United States or an informal agreement entered into by state administrative officials. The formal compact usually establishes a commission charged with certain responsibilities and confers authority to enforce compliance with its orders. The informal compact provides for a commission to formulate a program which will be executed by various agencies of the states subscribing to it. The informal compact is perhaps the best since it is flexible and retains operating authority within the states rather than delegating it to a commission without direct responsibility to the citizens.

Twelve compacts or agreements are now in force between groups of states. They are administrated by health agencies or sanitary water authorities. Table 17. The table shows that 33 states are working cooperatively for the control of interstate stream pollution. This group of states includes about one half of the total territory of the United States and all of the heavily industrialized areas.

The various commissions established by these compacts have the authority to investigate plant operation; to issue directives as to the type of abatement necessary; to require specific progress in abatement procedures during a given period; and to establish a date for full compliance with the directive. Stream conditions are based upon physical, chemical, and bacteriological standards rather than upon a definite health hazard or nuisance. Cooperation of industry will help eliminate industrial waste discharges and close liaison with state health agencies will forward programs for the construction of sewage treatment works.

Various methods of classifying natural bodies of water have been tried in connection with the establishment of standards. The general administrative procedure has included conferences with representatives of all

TABLE 17

*Stream Pollution and Sanitation Compacts*

| Title | Year Authorized | Type of Agreement | States Participating | Object |
|---|---|---|---|---|
| International Joint Commission | 1919 | Treaty | U. S., Canada | Control pollution Great Lakes from Lake Superior to Lake Huron. |
| Ohio River Interstate Stream Conservation Agreement | 1924 | Informal | Ill., Ind., Ky., N. Y., Ohio, Pa., Va., W. Va. | Abate pollution in streams of benefit to all. |
| Tri State Compact | 1925 | Informal | Del., N. Y., Pa. | Control use of the Delaware River and pollution thereof. |
| Great Lakes Drainage Basin Sanitation Agreement | 1928 | Informal | Ill., Ind., Mich., Minn., Miss., Ohio, Pa., N. Y., Wis. | To cooperate with each other and the United States Public Health Service to abate pollution of the Mississippi River. |
| Upper Mississippi Agreement | 1935 | Informal | Ill., Ind., Ia., Minn., Mo., Wis. | Abate pollution of the Mississippi River. |
| Interstate Sanitary Commission | 1936 | Formal | Conn., N. J., N. Y. | Control future, abate present pollution in rivers and tidal waters. |
| Interstate Commission on the Delaware River Basin | 1936 | Formal | Del., N. J., N. Y., Pa. | Agreement becomes law of each state to abate pollution of lower Delaware River. |
| New England Water Pollution Control Commission | 1936 | Formal | Conn., Mass., N. Y., R. I. | Control of any stream lying in territory of two or more states. |
| Red River Basin Sanitation Commission | 1938 | Formal | Minn., N. D., S. D. | Control pollution Red River of the North. |
| Interstate Commission on the Potomac River Basin | 1940 | Formal | D. C., Md., Va., W. Va. | Abate pollution in rivers of the basin. |

TABLE 17—Continued

| Title | Year Authorized | Type of Agreement | States Participating | Object |
|---|---|---|---|---|
| Ohio River Valley Water Sanitation Commission | 1940 | Formal | Ill., Ind., Ky., N. Y., Ohio, Pa., Va., W. Va. | Abate pollution in drainage area of the Ohio River. |
| Missouri River Basin Health Council | | | Col., Ia., Kan., Minn., Mo., Mont., Neb., S. D., Wy. | |
| Northwest Waterworks Control Pollution Council | | | Ida., Ore., Wash. | |

activities interested in stream pollution control. Both official and nonofficial organizations, including those who contribute the wastes and those who desire to use the water, are allowed to give their viewpoints. Industry must be represented since it will suffer the burden of control measures; health officials must be there; recreational interests must have representation and so must industries who will utilize the available water in manufacturing. Efforts are exerted to reach agreement on the levels of pollution to be permitted. This is usually a compromise between the demands of public health officials, the economic interests of industry, and the desires of sportsmen and recreational enthusiasts.

Standards of allowable pollution have been set up based upon whole river systems, upon zones of rivers, or individual regions. In any case, the standards established should reflect the present and future use of the stream, and balance public demands against industrial and municipal economies. The present trend is to regulate pollution on a regional basis. The State of California State Water Pollution Control Board[51] has accepted the regional basis for control and says of this method:

1. The uses of waters within a zone are by no means uniform throughout the zone.
2. The effects of pollution are not uniformly dispersed throughout a zone from a source of pollution but are restricted in geographical extent.
3. The successful program must recognize that the need for economical waste disposal is just as exacting as the need for protection of water quality for beneficial uses.

4. A zoning program tends to be fixed or permanent, and does not lend itself to a program of reclaiming lost water quality or upgrading a degraded area.

## State Control Activities

The Pennsylvania Sanitary Water Board was the first state policy-fixing and regulatory organization created for the control of water, sewage, and stream pollution. Instituted in 1923, the policies, programs, and regulations adopted by this Board have offered a precedent for other state organizations created since its inception. The classification of streams as laid down by this Board was as follows:[25]

*Class 'A'*

**Relatively Clean and Pure Streams.** "Streams in their natural state probably subject to chance contamination by human beings but unpolluted or uncontaminated from any artificial source, hence generally fit for domestic water supply after chlorination, will support fish life and may be safely used for recreational purposes."

*Class 'B'*

**Streams in Which Pollution Shall Be Controlled.** "Streams more or less polluted, where the extent of regulation, control, or elimination of pollution will be determined by a consideration of (a) the present and probable future use and condition of the stream; (b) the practicability of remedial measures for abatement; and (c) the general interests of the public through the protection of the public health, the health of animals, fish and aquatic life, and the use of the stream for recreational purposes."

*Class 'C'*

"Streams now so polluted that they cannot be used as sources of public water supplies, will not support fish life, and are not used for recreational purposes, and also from the standpoint of the public interests and practicability, it is not necessary, economical, or advisable to attempt to restore them to a clean condition."

Creation of these regulatory bodies has materially aided in the development of plans and procedures that best fit local needs for curtailing pollution. As would be expected, activities of this nature have been more pronounced in those states of greatest population and industrial activity.

As shown by Table 18, forty-two states have instituted stream pollution control. The analysis of a nation wide survey of abatement programs com-

TABLE 18

*Agencies Responsible for Stream Pollution Control*

| | |
|---|---|
| (a) State Department of Health only | 10 states |
| (b) Agency separate from state department of health but closely allied to it, with technical service furnished by the state department of health and a representative of that department serving as a member of the separate agency | 11 states |
| (c) State department of health and other agencies | 17 states |
| (d) Water pollution control board separate from state department of health handling all water pollution control activities | 4 states |
| (e) No state agency | 6 states |

Warren J. Scott, Sewage Works Journal, **19:** 883 (1947).

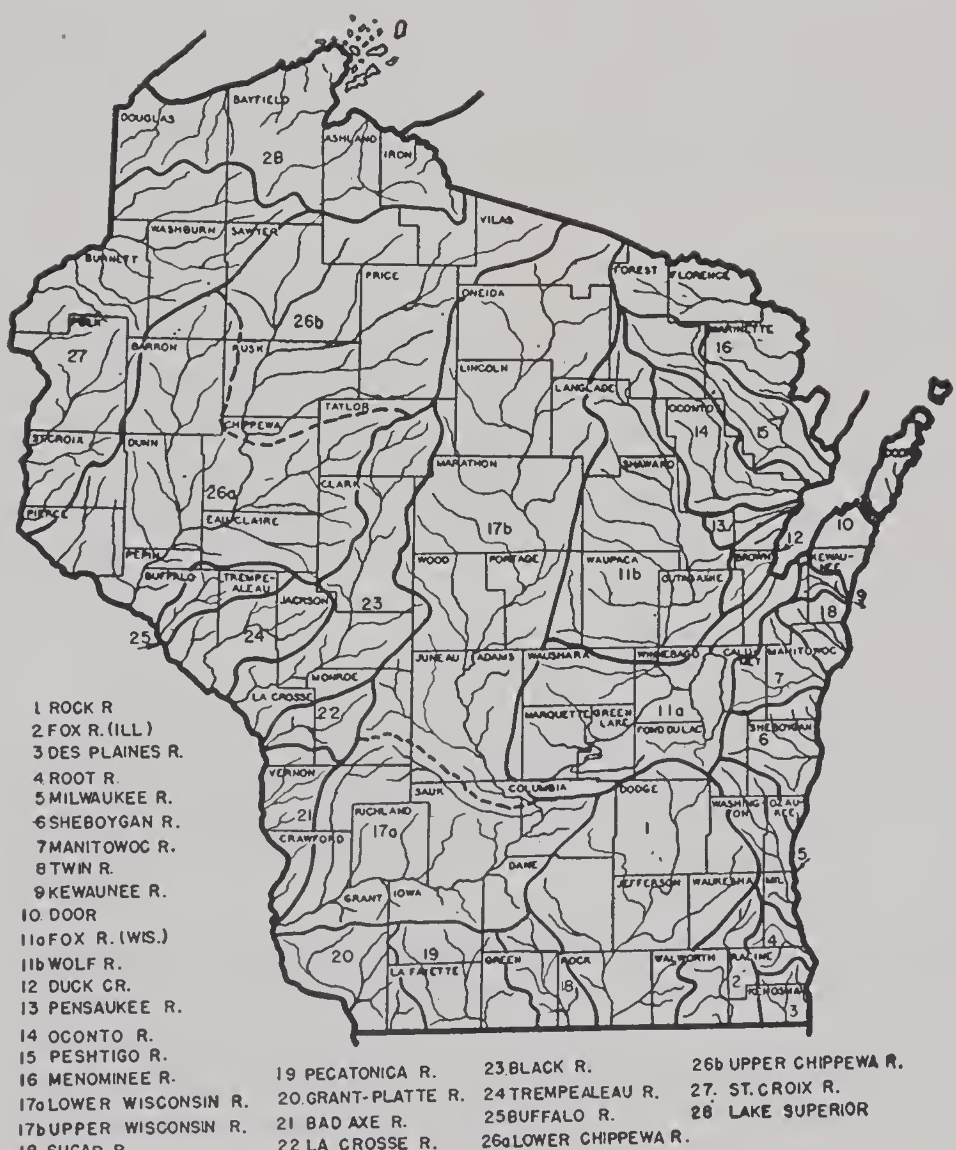


FIG. 70. Wisconsin drainage areas as established for stream pollution control. (Courtesy, Sewage and Industrial Wastes Engineering.)

piled in 1946[46] indicates extensive activity. Programs are meeting with excellent industrial cooperation and are administered upon this premise rather than upon the police powers of the state.

The New Castle County Sanitary District in Delaware was formed in 1945 for the only industrial area in that state, while the Buffalo, N. Y., Sewage Authority was created in 1936 to eliminate pollution in the Niagara

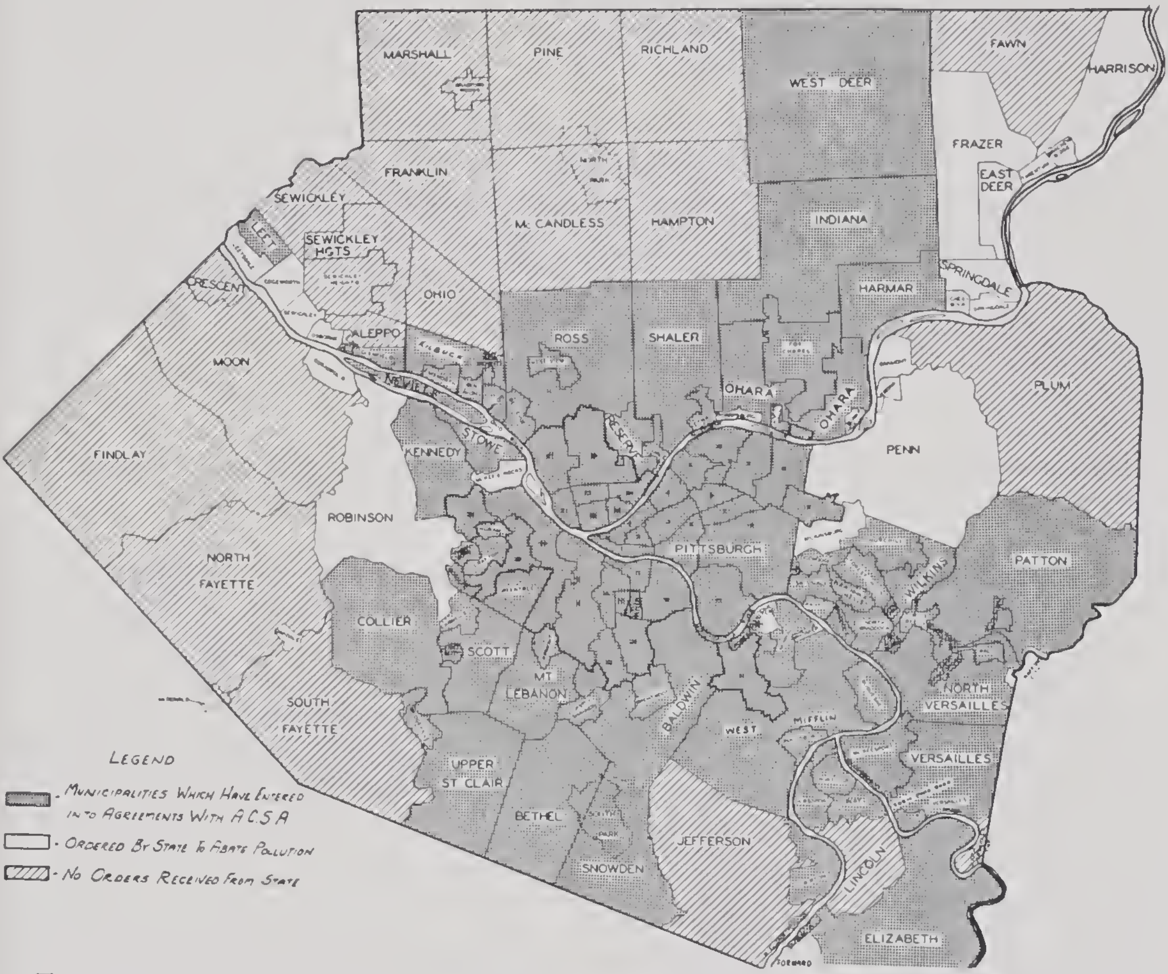


FIG. 71. Stream pollution control by the Allegheny County Sanitary Authority. (Courtesy, Sewage and Industrial Wastes Engineering.)

River. Every mile of the major rivers in West Virginia is being classified as to water quality and zoned for the degree of treatment required. In Wisconsin the state has been divided into 28 major drainage districts and the rivers zoned in relation to quality. The Allegheny County Sanitary Authority created in 1946 has an active program for the reduction of domestic and industrial pollution in 127 communities adjacent to Pittsburgh, Pa.

The Pennsylvania State Department of Health in 1946 required the preparation of plans and construction of 564 sewage treatment works for various communities of all sizes including Philadelphia, Pa., and waste disposal plans from 613 industries. The type of treatment depends upon the quality

characteristics of the stream concerned. Money grants totaling $4,250,000 for fifty percent of the cost of plans for treatment plants are available to municipalities and industry. Grants are not available for actual construction.

In addition, a comprehensive desilting program for the Schuylkill River is being completed at a cost of $35,000,000. Some 4,100,000 tons of clum (coal and mud) worth about $15,000,000 have been removed from the river bed. Suspended solids in the river are now about one tenth of one percent of the former load.

In 1943 the state of Illinois brought suit against the state of Indiana to restrain Gary, Hammond, East Chicago and Whiting, Ind., and 20 industries in those areas from discharging wastes into Lake Michigan, the source of water supply for Chicago, Ill. This suit has been adjudicated without court decision by the cooperation of the responsible state officials and industry executives to abate the pollution.[46]

## Public Law No. 845

Federal water pollution control became effective in Public Law No. 845 on June 30, 1948. The objects as stated in Section 1 are:[40]

> that "it is hereby declared to be the policy of Congress to recognize, preserve, and protect the primary responsibilities and rights of the states in controlling water pollution, to support and aid technical research to devise and perfect methods of treatment of industrial wastes which are not susceptible to known effective methods of treatment, and to provide federal technical services to state and interstate agencies and to industries, and financial aid to state and interstate agencies and to municipalities, in the formulation and execution of their stream pollution abatement programs."

The Act further provides:

> that "the pollution of interstate waters . . . which endangers the health or welfare of persons in a state other than that in which the discharge originates, is hereby declared to be a public nuisance and subject to abatement as herein provided."

Under Section 2 the Surgeon General of the United States Public Health Service is authorized:

> "in cooperation with other federal agencies, state water pollution agencies and interstate agencies and with the municipalities and industries involved, to prepare or adopt comprehensive programs for eliminating or reducing the pollution of interstate waters where such pollution endangers the health or welfare of persons in another state than that where the pollution originates. The State Health Department is recognized as the State Water Pollution Agency unless other state agency is provided."

In case there is failure to abate pollution The Federal Security Adminis-

trator after a public hearing, and with the consent of the state pollution agencies, may request the Attorney General of the United States to bring suit on behalf of the United States to secure abatement.

The Surgeon General of the United States Public Health Service may

> "upon request of any *state water-pollution* agency or interstate agency, conduct investigations and research and make surveys concerning any specific problem of water pollution confronting any state, interstate agency, community, municipality, or industrial plant, with a view to recommending a solution of such problem."

He also shall

> "prepare and publish, from time to time, reports of such surveys, studies, investigations, research, and experiments made under the authority of this act as he may consider desirable, together with appropriate recommendations with regard to the control of water pollution."

Loans at 2 percent interest limited to one third the estimated cost may be made to

> "any state, municipality, or interstate agency for reports, plans and the construction of treatment works for pollution abatement."

These loans are limited to $250,000 to any one agency and prior approval of the Surgeon General must be secured.

There is also established in the United States Public Health Service a Water Pollution Control Advisory Board of eleven members composed of a representative from that service; the Department of the Army; Department of Interior; Federal Works Agency; Department of Agriculture and 6 persons at large appointed by the President representing industries, municipalities and state governments. This Board reviews the policy and programs of the United States Public Health Service as administered under the law. Funds were provided for grants to aid agencies in research and study of stream pollution problems. Regional offices have been created by the United States Public Health Service to coordinate federal pollution control policy with state agencies. Basin control boards including membership of state authorities concerned have been established in each area for the purpose of developing stream standards and abatement procedures. However, the United States Public Health Service will coordinate basin policy and furnish funds for regional operation so it is apparent that little autonomy is left to the states under this program insofar as interstate streams are concerned.

## STREAM POLLUTION SURVEYS

Stream pollution surveys are an essential part of water quality control. Facts concerning prevailing conditions must be obtained to establish

effective safeguards which will accomplish the desired results without detriment to major public interests.

Any comprehensive program for controlling the pollution of an entire river system, with due regard to the protection of public health and aquatic life, fair distribution of the burden of control, and reasonable economy, necessitates the collection and careful consideration of certain fundamental data. A large portion of these data must be obtained by a thorough scientific investigation of stream conditions. This investigation, or survey, has as its objects:

Determination of the nature, location and extent of pollution.

Evaluation of the present use of the stream as contrasted with potential value if stream were used for greatest good to most people involved.

Ascertaining the effect of the pollution on the aquatic life and general stream conditions, particularly those bearing on usefulness of the stream to man.

Determination of the extent of and agencies influencing natural stream purification, or recovery from polluted conditions.

Providing data for evaluating improvement in stream conditions affected by remedial measures.

## General Data

The physical conditions that may have material influence on pollution conditions and recovery, or natural purification, of a stream need to be ascertained. This usually covers a large number of items, such as location of sources of pollution, dams, rapids, tributaries, etc., all of which can be assembled to advantage on a map of the draining area. Additional data concerning the area and character of watershed, climatic conditions, increase and spread of population, actual and potential industrial development, should be secured. Uses of the stream should be definitely determined. The extent of damage to interests involved should be evaluated if possible. Locations of sludge banks or deposits and occurrence of floating debris should be determined. All pertinent facts need to be carefully considered to establish and control stream sampling procedures involved in the survey.

## Stream Flow Data

Considerable information is already available covering stream flows for major rivers in the United States through the records of the United States Geological Survey. Reports of state agencies regulating water power or charged with the conservation of water resources are other sources of information. If such information is not available for the particular stream being surveyed, it usually proves necessary to establish flow gauging stations.

Long time records of stream flow are most helpful in studying pollution

data. These records are used for comparing stream flow conditions existing during the surveys with those of previous years. They serve as a basis for predicting future conditions, giving an idea of the extreme minimums of flow available to dilute the wastes entering them. The periods when stream flow regulation would be beneficial or necessary from the pollutional point of view are indicated by these data.

## Analysis Data

The results of bacteriological tests are most helpful in determining the public health hazards and particularly essential in establishing the degree of load on water purification plants, assuming the stream is to be used as a source of drinking and domestic water supply. Also, the results are very useful, especially when considered with other data, in tracing the progress and extent of pollution. The usual bacteriological analyses made in a stream survey determine total numbers of bacteria and organisms of the coli-aerogenes group. The latter determination, being indicative of fecal pollution, is most significant. Results are generally expressed as *B. coli* indices, or "most probable numbers" (M.P.N.) of organisms of the coli-aerogenes group per 100 cc. of water.

In addition to dissolved oxygen and B.O.D. determinations, other analyses of importance include: total, suspended and volatile solids; total organic, nitrite and nitrate nitrogen; alkalinity, or acidity; pH; physical determinations, including color, odor and turbidity; and special tests, depending on the nature of the pollution. The volatile suspended solids are of particular significance for information of offensive sludge deposits since they are a measure of the total organic content of the sample.

The tests for nitrogen are of importance in connection with stream pollution by sewage as it is one of the more valuable indices of the strength of a sewage and the extent of sewage pollution, and also of the natural changes that may have taken place through such pollution. The presence of nitrates with little or no free ammonia or nitrites indicates that the nitrogenous content of the organic matter has been stabilized or is in a condition to be used as food for aquatic vegetation.

The determinations of alkalinity or acidity and pH value indicate the effect of the waste on aquatic life. Certain fish and plant life in streams are known to be very susceptible to changes in the character and degree of acidity or alkalinity of the water. The physical determinations such as color, odor, turbidity, etc., are often of minor importance and are used only as aids in the interpretation of other results.

## Biological Studies

Pollution surveys, particularly where the effect on fish life is of paramount importance, need to include comprehensive biological studies. Liv-

ing indicators of the intensity of stream pollution include certain common and readily recognizable water plants and animals. These biological forms are so selected as to offer a fairly reliable index to the oxygen content of a stream, which in turn measures the degree of pollution. Such indicators of pollution are summarized by the New York State Conservation Commission[26] as follows:

> "Water molds and scums, particularly if of colors other than green, indicate decreasing oxygen—conditions are not favorable and may be worse downstream.
>
> "Tubifex (worms) marks approximately the limit of fish life.
>
> "Rat-tail maggots, if abundant over the whole bed of the stream, are an almost certain indication of prohibited pollution.
>
> "Bloodworms indicate recovery and conversion of wastes into fish food.
>
> "Green plants, mosses, silks and nets usually indicate good and improving conditions."

Resistant organisms, such as sludge worms, rat-tail maggots, sewage fly larvae, sewage fungi or water mold and mud worms are those that are to be found in the zone of maximum oxygen depletion. In the zone of pollution and recovery tolerant organisms will be found, such as snails, sow bugs or isopods, water boatmen, water shiners, pine-weed shiners, and bullheads or catfish. The sensitive forms from well aerated water of normal unpolluted streams include such examples as: water net, caddis worm, dragon fly, stonefly, snail, and water moss. Game fish may be expected to thrive where these forms are found.

## Types of Industrial Wastes and Control Procedures

Knowledge of the character and effect of sewage and other wastes is necessary to permit proper interpretation of stream analyses and is essential to the development of corrective measures. The population contributing to sewerage systems is an index of pollution loading by domestic sewage, but since trade wastes are frequently discharged with domestic sewage, it may be desirable to measure the amount of pollution discharged daily. Volumes of the sewage and wastes can be determined by measuring over weirs, or other measuring devices employing well known hydraulic principles. Composite samples, or the total of samples taken at fixed intervals for a period usually of twenty-four hours, proportioned as to flow, are collected for chemical analyses of constituents.

Probably the most common pollution characteristic of sewage and industrial wastes is its requirement for oxygen. This may be a chemical or a biological oxygen demand, or a combination of both, depending on the nature of the waste. Since the depletion of dissolved oxygen in a stream generally causes a nuisance, the biochemical oxygen demand of industrial wastes may be regarded as a measure of offensiveness. Accordingly, the

5-day biochemical oxygen demand determination has come into widespread use for evaluating "offensive" pollution occasioned by wastes.

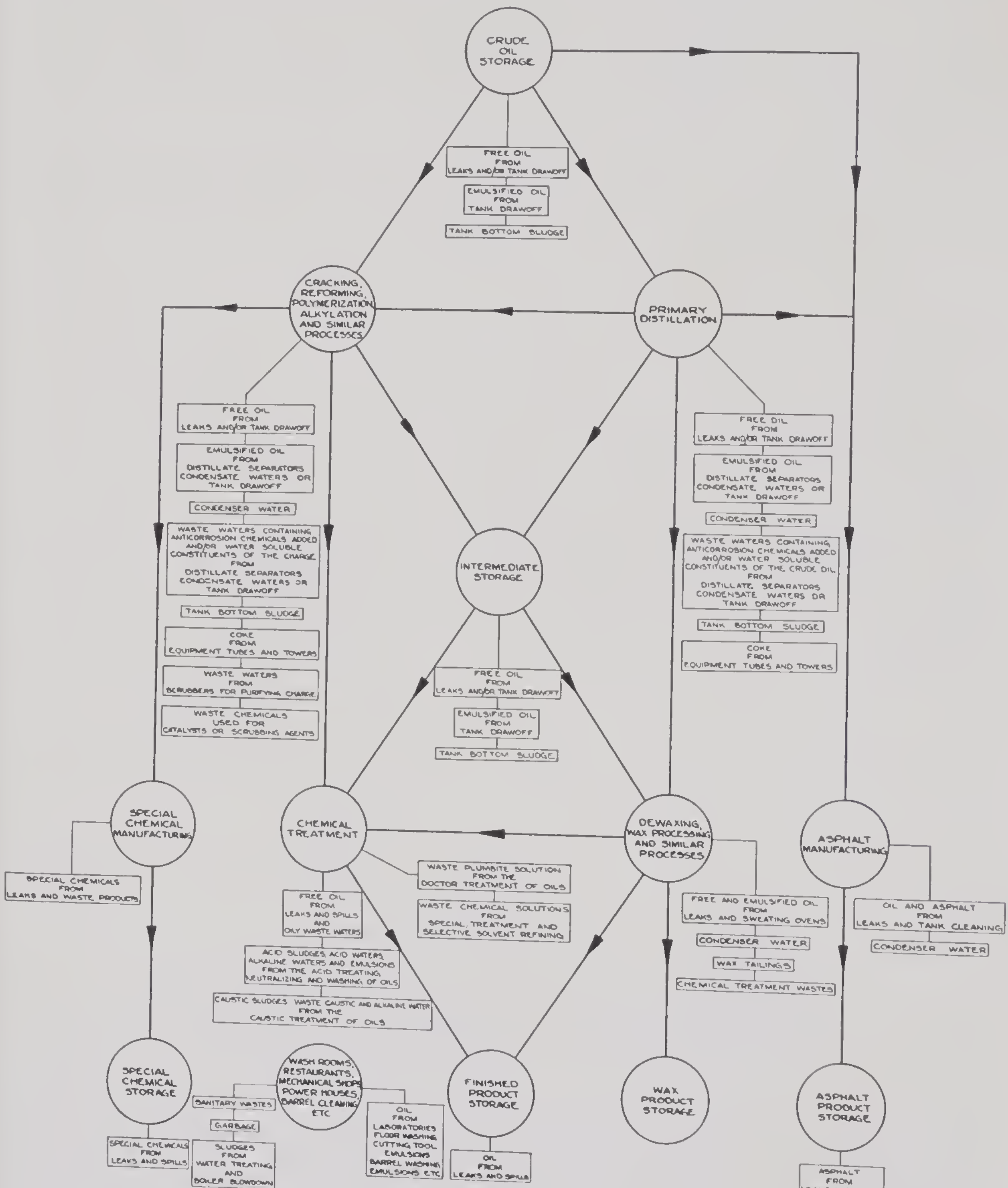


FIG. 72. Wastes produced in petroleum refining. (Courtesy, W. B. Hart, The Atlantic Refining Co.)

Consideration is also being given to the use of the oxygen consumed test, which indicates the concentration of carbonaceous matter, and the total nitrogen test as alternate measures of industrial pollution.

The development of processes of waste utilization is primarily in the interest of industry. Accordingly, the technical and financial support neces-

sary to devise practical and effective methods for re-use or recovery of pollutional substances in the wastes should be furnished by industry. Evaluation of the effectiveness of processes devised for the removal of pollutional constituents and in the elimination of nuisances, is more the function of governmental agencies. For most satisfactory results cooperative programs are regarded as fundamental.

It is desirable to separate the various wastes in a plant since in many instances it is more economical to handle each separately. Those wastes having polluting components and so requiring treatment should be segre-

TABLE 19

*Abridged List of Industrial Wastes*

| Inorganic | Organic | Mixed |
|---|---|---|
| Brass and Copper | Vegetable Canning | Textile |
| Iron and Steel | Corn Products | Dyeing |
| Plating | Alcohol Production | Coke and Gas Wastes |
| Sulfur Mining | Slaughter House | Paper Board |
| Sand Washing | Dairy and Milk | Laundry |
| Acid Manufacturing | Beet Sugar | Tanning |
| Salts | Citrus Fruit Canning | Cutting Oils |
| Alkalies | Brewery | Dye Manufacture |
| Coal Mining | Meat Packing | Petroleum |
| | | Plastics |
| | | Rubber Reclaiming |
| | | Rubber production, natural and synthetic |
| | | Explosives |
| | | Vegetable Dehydration |
| | | Wool Scouring |

Water Works & Sewerage, December 1945, page 391.

gated from the frequently large volumes of cooling and other process waters not requiring treatment. Reconstruction of old and laying of new sewer lines in the factory is often justified when efforts are being made to reclaim or segregate the wastes for subsequent use or treatment. Facts obtained from plant surveys giving kinds, quantities and points of origin of wastes are the basis for the planning of corrective measures. The degree of treatment necessary, consistent with stream usage, can be determined from the information gathered. A list of the common industrial wastes will be found in Table 19.

## Utilization of Wastes

Reclamation of wastes, particularly if accomplished with a substantial profit over operating expense, unquestionably is the most attractive pro-

cedure from the industrial point of view. While this may only be feasible with a limited number of wastes, experience of the pulp and paper industry, for example, has definitely shown that considerable savings accrue by the installation of "save-all" for white-water recirculation systems in many cases. Results of mill surveys indicate the practicability of keeping fiber losses under 1 percent and volumes of waste below 20,000 gallons per ton of product.[31] Progress has been made in recovering proteins from meat packing plant wastes, cattle food from malt house wastes and distillery slop, casein from milk waste, and other valuable by-products from pollutional wastes discharged by a number of industries. Improved evaporating and drying equipment for producing powdered whey should provide a profitable method for eliminating strong milk plant waste from city sewage. By carrying waste utilization to its economic limits, the need for further treatment of effluents from some industries before discharge into public sewerage systems or water courses may be eliminated or greatly minimized. Careful operation, development of methods for waste water re-use, use of wastes for by-product and improved manufacturing procedures often reduces general industrial operating costs and also decreases stream pollution.

The first and most promising step in solving various pollution problems of industry is the prevention of waste at its source. The work should start with a careful study of each step in the manufacturing process. The preparation of flow charts or designs, is helpful in determining where material formerly wasted may be returned to the process. The first effort usually should be directed toward reprocessing or recirculation of wastes, exhausting all possibilities of simple and inexpensive changes to effect direct recovery within the plant. Industry is actively developing procedures for the utilization of its wastes.[3, 4, 8, 13, 15, 23, 28, 34]

## Trade Waste Treatment by Industry

A large number of industries, having exhausted possibilities of economic utilization of wastes, are confronted with problems of treatment and disposal.

The wastes which appear to have received major attention are those from the following industries: canning, chemical, coal mining, coke (by-product), dairy products, distilling, gas manufacture, laundering, metal works, oil refinery, meat packing, pulp and paper, sugar, tannery and textile establishments. The procedures employed for removal of pollutional constituents may be broadly classified as mechanical, chemical, and biological. Combinations of these basic procedures have been used in the treatment of the wastes. They seek to:

remove sizable suspended solids by screening or settling; remove fats, oils and greasy solids by flotation and skimming procedures, aided in

some cases by chemical treatment; remove colloidal solids by flocculation with chemical coagulants, followed by settling and possibly filtration; neutralize excessive acidity or alkalinity by addition of chemicals; remove or stabilize dissolved solids by chemical precipitation, or biological processes, or combination of both; decolorize by chemical treatment, with settling or filtration, singly or in combination; and re-oxygenate the wastes by suitable aeration.

The pulp and paper industry is an example of one industry that has instituted stream pollution control methods based on the results of studies conducted by and for the industry. In the sulphite wood pulping process about 50 percent of the dry weight of the wood and sulphite are dissolved in the water liquor. Screening and vacuum evaporation of this waste produces a material suitable for fuel. Some of the other constituents such as furfural and aldehydes are of value in the chemical industry. The recovery of fiber by rotary vacuum "savealls" with chlorination of the recirculating "white water" has reduced fiber loss to about 1 percent.[5]

Screening, centrifuging followed by evaporation of the slop from distillery mash with subsequent heat drying has made possible the conversion of this waste to cattle food. It is profitable recovery since one million tons of food are sold yearly at a value of $30 per ton. In small distilleries this slop is given to the farmer to be used as cattle food or to be spread as fertilizer, procedures that are wasteful of the chemical constituents of the mash.

Textile wastes consist of grease and hair from wool scouring; acid from rayon filament baths; dye wastes and Kier wastes from mercerizing. Neutralization of the acid waste is now standard practice while centrifuging is used to collect the hair and grease, permitting the re-use of the water. Kier waste should be treated separately either by neutralization with carbon dioxide directly or by storing it in lagoons for several days so that the carbon dioxide can be absorbed from the atmosphere. Neutralization of this waste is essential since the high alkalinity inhibits bacterial and biological life of a stream. Acid cracking, addition of calcium chloride, and chlorination of wool waste effluents prior to centrifuging makes possible the recovery of 98 percent of the grease. When unmarketable this grease is burned. Sulfur dye wastes may be clarified by coagulation with ferric chloride and sedimentation, and then added to domestic sewage.

Cannery wastes are very putrescible and have a high oxygen demand. Since canning is a seasonal industry and facilities are frequently locally owned, it is often difficult to persuade the canner to install adequate waste recovery equipment. Screening of the wastes to remove large vegetable particles, followed by lagooning with the application of lime to neutralize acidity and the addition of sodium nitrate to support oxidation, is common practice. The effluent from most lagoons should be treated further on bio-

filters to produce a low B.O.D. but financial considerations up to now have precluded this additional treatment.

Liquid wastes from steel plants consist of water from cooling, coke quenching, and pickling liquor. By-product coke plant liquor may also be present. Of these the coke plant and pickling liquors require treatment. Extraction processes for the recovery of phenol in the coke plant liquor are based upon treatment with caustic soda and naphtha (Koppers process) with conversion to sodium phenalate and phenol. Phenol compounds find a market in the plastics industry. The coke liquors may also be used to quench the hot coke with volatilization of the phenol. Small concentrations (20 to 30 ppm.) of phenol may be admixed with raw sewage without reducing the efficiency of the sewage treatment process. Pickle liquor containing about 1 percent ferrous sulfate is neutralized and the sludge removed by lagooning. Vacuum filtration of sludge is being introduced and a new oxidation process has been developed that precipitates the sludge very rapidly. Disposal of pickle liquor is a problem of magnitude since about 686,000 tons of ferrous sulfate is discharged yearly.[12]

Milk plant wastes have a high B.O.D. (1300 ppm.) and solid content (4500 ppm.) and also become acidic due to the formation of lactic acid from souring by bacterial action. Treatment by bio-filtration produces a stabilized effluent that can be discharged with adequate dilution into streams or other bodies of water.

Drainage from abandoned coal mines is acid due to the oxidation of sulfur by the atmosphere and the eventual formation of sulfuric acid. Acid mine waters are very corrosive and are a stream pollutant. Elimination of this drainage by sealing the mines to exclude air has been practiced extensively in Kentucky, Pennsylvania, Ohio, Maryland, and West Virginia.[7, 27, 42, 49] This is a current program, requiring several more years of work, but when completed it will eliminate acid drainage into the rivers.

Tannery wastes are putrescible and frequently contain toxic and corrosive materials. Hides are pickled in brine or sulfuric acid, dehaired with lime or dimethylamine and tanned with vegetable substances or chromic acid. These wastes will be sufficiently treated by passage through primary sedimentation tanks with a detention of 8 hours followed by bio-filtration. Chrome tanning wastes are difficult to treat because the chrome salts inhibit biological action in the filters. Sand filters have occasionally been utilized for final treatment.

## Disposal of Trade Wastes with Domestic Sewage

Industries located in urban territory usually discharge wastes into the nearest sewer. Detrimental effects to sewerage system structures, overloading of treatment works, complaint of nuisance and increased stream

pollution have frequently resulted. Early efforts to secure proper solution of these industrial waste problems generally met with considerable opposition from industry management. Much of the trouble encountered was due to a lack of a clear understanding between the public and industrial plant officials as to the division of responsibility. Nearly every industrial community has this problem.

Information obtained from various state sanitary engineers indicates that there is no uniformity of policy with respect to the discharge of various


FIG. 73. A sealed abandoned mine. (Courtesy, George L. Hall.)

trade wastes into public sewerage systems. Where legal requirements have been established, they have usually been in the form of authorization permitting some designated agency to specify conditions under which use may be made of a sewerage system. The principal guiding factors from the technical point of view in making decisions as to whether trade wastes should be allowed to discharge into municipal sewers are: freedom of waste materials that will adhere to sides, or deposit in sewers; exclusion of inflammable or explosive substances; absence of acids which would injure or materially accelerate deterioration of sewerage structures; elimination of steam or very hot liquids that would damage sewers, and removal of constituents of wastes that seriously interfere with the operation of the sewage treatment works. While all types of industrial wastes are found in urban

sewers, those from packing houses, breweries, metal plating plants, and laundries are examples commonly encountered.

In large cities the dilution given to industrial wastes by domestic sewage often removed serious treatment problems. Packing house wastes increase appreciably the load on a sewage treatment works. Offal, blood, manure, and hair is converted by vacuum evaporation to "tankage" and utilized in the commercial manufacture of fertilizer. However wash waters from these plants carry considerable grease, blood, and other organic material into the sewer, necessitating ultimate disposal at the municipal treatment works. In small municipal sewage plants treatment of these liquids by bio-filtration after primary sedimentation of the combined sewage produces a satisfactory effluent. This process is also used at large packing houses prior to discharge of the wastes into city sewers.

Brewery waste, consisting of yeast residue, bottle washings, and spent grain liquors are high in B.O.D. There is every indication that recovery of stock food from these wastes would be profitable. There has been little study of this subject and these liquids are usually discharged into the municipal sewer for final disposal at the treatment works. This waste can be a considerable factor in the sewage treatment processes as is shown by the 28 breweries in Chicago, Ill., which produce a B.O.D. equivalent to a population of 210,000.[19]

Metal plating establishments using small town sewage systems or separate septic tank disposal frequently cause serious pollution of small streams by the discharge of cyanides into them. Since the toxicity of these wastes can be destroyed by treatment with 6 ppm. each of chlorine and caustic soda per ppm. of waste, this neutralization at the plating establishment should be mandatory. This action should also be taken before the waste is discharged into large sewerage systems.

Laundry wastes are not a problem in the big city systems but may become so in the small sewage plant or septic tank. Under these conditions the soapy alkaline waste creates an increased volume of scum and reduces the efficiency of the tanks. Acidification with sulfuric acid or carbon dioxide, followed by coagulation with alum produces a settling sludge. Final treatment by bio-filters gives a satisfactory effluent.

There is a growing trend to charge industry sewer rental to compensate for the increased cost of the treatment works operation and sewer maintenance. New Brunswick, N. J.,[45] has established a rate of \$22 per million gallons discharged plus \$5 per ton of solids in the waste and \$5 per 100 pounds of chlorine demand required by the waste. These charges are billed quarterly with recording meters installed on large flows to measure the volume, or they are billed on the basis of water consumption for small plants. Tests of the waste characteristics are made by the city semi-yearly.

Rental plans of this type are just, since they place a share of the increase in operation costs upon the waste contributor responsible for them. Industrial waste treatment must be considered as an inherent cost of manufacturing comparable to that of raw materials and labor.

## CONCLUSIONS

In the early history of our country when population concentrations were low and industrial development was still of a pigmy stature, need for water was not a large order. Bodies of clean water were available for satisfactory dilution of industrial wastes which did not interfere with the recreational use of the water. Our present high concentration of population and industry create a demand for enormous quantities of clean water. Quantities of sewage and industrial wastes have grown correspondingly. The health and economic future of many areas of the United States depend upon the preservation of our natural water supplies in a clean state.

Information has been presented to show the general procedures being carried out in the effort to solve industrial waste problems. The essential approach lies in the active cooperation of industries concerned in a program consisting of: waste utilization and recovery to the greatest possible degree; reduction of the amount of waste products produced; and then, if a problem of pollution still exists, installation of any effective and practicable method available or capable of being developed to treat and dispose of the waste in a satisfactory manner.

The support of industrial management through the many associations conducting research and study projects in pollution prevention and treatment is good evidence that industry is now aware of its waste problems and is cooperating to avoid unnecessary pollution of the waters into which industrial wastes must be discharged.

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Chapter IX

# DISPOSAL OF REFUSE AND SOLID WASTES

"The efficient collection of municipal wastes consists of providing the proper amount and character of service in a sanitary, dependable and economical manner."[9]

Municipal wastes include garbage, ashes, street sweepings, dead animals, rubbish and trade wastes. Of these only the last two require further definition. Rubbish includes paper, boxes, boilers, abandoned automobiles, scrap iron; trade waste includes all of the above as well as waste building materials and factory products.

While in a large municipality the producer of trade waste may be required to pay for the disposal of his own product, he must, in general, be closely supervised so that the disposal is done in accordance with the rules for health laid down by the authorities in charge.

There is a wide variation in the quantity of refuse produced per capita in different municipalities, just as there is in different seasons in the same municipality. The characteristics of the inhabitants, and the frequency of collection are the factors of greatest importance, although other influences also exert an effect. The data given in Table 20 may be used for estimation and not as a standard for any particular city. Table 21 showing the physical characteristics of refuse indicates the many variable constituents. Garbage is about 25 percent by weight and 18 percent by volume of the total refuse collected; rubbish is 30 percent by weight and 55 percent by volume, and ashes 45 percent by weight and 25 percent by volume of the total when collected separately.

The public health significance of the disposal of refuse and solid wastes differs with the nature of the material. Garbage, street sweepings which may contain manure, or other wastes that may have organic constituents are of importance because they may serve as food supplies for rats or insects. Dry refuse, trade wastes, and rubbish frequently harbor rats and insects even though they may not serve as a source of food. Actually, it is difficult to obtain a complete separation of garbage from dry refuse or rubbish. The hazards from rats are well known. Insects that may find breeding haunts in garbage and refuse are the house and blow flies, cockroaches, and crickets. Although these insects may not all present direct health hazards, they can develop into first class nuisances. The smoldering, odoriferous dump can also provide numerous vexatious complaints for the health department.

The disposal of wastes is a governmental function and a service demanded in every urban community.[20] Up to the past decade the usual method of

garbage disposal was by hog feeding and of rubbish by dumping. With the introduction of the sanitary fill, extensive development of incinerators, and improved collection trucks and procedures, solid waste collection and disposal has assumed its place as a protective measure for public health.

The present magnitude of the garbage and refuse disposal problem can be measured by the current need for new facilities. The United States Public Health Service, in 1946, made a nation-wide survey of needed sanitation facilities. This survey showed that there were immediate needs of at least 1090 incinerators and the establishment of 5549 sanitary land fill installations. The estimated costs of these two items was in excess of $100,000,000. In addition, more than 12,000 trucks and land fill sites were required to the extent of $70,000,000 in valuation.[21]

TABLE 20

*Garbage and Refuse Collection and Disposal*

Data Sheet

| | | |
|---|---|---|
| Quantities Produced: (Median) | | |
| Garbage | 0.7 lbs./capita/day | 900 lbs./cu.yd. |
| Rubbish | 0.9 " " " | 214 " " " |
| Ashes | 1.1 " " " | 1250 " " " |
| Total Combustible | 1.2 " " " | 440 " " " |
| Total Incombustible | 1.5 " " " | 885 " " " |

| | | | |
|---|---|---|---|
| Character of Collection: | | | |
| Garbage | 70% moisture | 10% ash | 20% combustible |
| Rubbish | 13% moisture | 17% ash | 70% combustible |

TABLE 21

*Combustible Characteristics of Municipal Refuse in Percent**

| Component | Moisture | Organic Combustibles | Ash | B.t.u. per Pound |
|---|---|---|---|---|
| Garbage | 70 | 20 | 10 | 2,000 |
| Rubbish | 13 | 70 | 17 | 7,000 |
| Ashes | 1 | 35 | 64 | 3,500 |
| Street sweepings | 36 | 25 | 39 | — |
| Mixed refuse | 42 | 33 | 25 | 4,000 |

* Courtesy of Henry W. Taylor, Consulting Engineer, New York, N. Y.

## Garbage and Refuse Collection

About 75 cities have instituted service charges for refuse and garbage collection, as noted in Table 22. These fees are collected from the person living in the house or apartment unit and actually constitute an increased

tax levy. When service is suspended due to delinquent accounts, sanitary hazards develop and good public relations fail. It is therefore questionable if collection fees enhance the basic object of refuse disposal, namely health protection, since people will resent and seek to evade service charges when cooperation is easily obtained with "free" service. Refuse collection and disposal costs should be a part of the general tax levy and not singled out as a fee service.

TABLE 22

*A Partial List of Cities Charging Rubbish Collection Fees*

| City | Cost Family Unit | Cost Business Establishment |
|---|---|---|
| Columbus, O. | $4.00 yearly | Garbage $.02 gal., refuse $0.10 bbl. |
| Youngstown, O. | 0.50 weekly* | Additional fee in excess 30 gals. wkly. |
| Portsmouth, O. | 0.60 monthly* | $.25 per 30 gal. can refuse & ashes |
| Dallas, Tex. | 0.90 monthly | $1.00 to $2.00 per month |
| San Francisco, Calif. | 0.40–1.75 weekly | |
| Stockton, Calif. | 0.50–1.75 weekly | $0.75–$6.00 per week |
| Palo Alto, Calif. | 0.65–3.00 month | Flat monthly charge based on quantity |
| Fresno, Calif. | 0.45–0.80 month | |
| Lansing, Mich. | 2 year as can rental | |
| Miami, Fla. | 4.00 yearly | |
| Oklahoma City, Okla. | 1.50 quarter | |
| Rochester, Minn. | 0.10 weekly | |
| Sacramento, Calif. | 0.50 monthly | |
| Tacoma, Wash. | 0.35 monthly | $0.08 each 30 gal. can |
| Little Rock, Ark. | 1.00 quarter | |

* Garbage only.

References: Smith, Chester A., Eng. News Rec., Apr. 10, 1941 p. 534; June 3, 1943 p. 822; January 30, 1947 p. 168.

**Frequency of Collection.** Garbage collections vary from daily to once a week in frequency. The usual norm is twice weekly. When separate collections are made for rubbish and ashes, they are made at about the same intervals as those for garbage. A recent study[7] disclosed that of all the cities reporting (almost 200, divided into 5 different population groups) 65 percent collect garbage and refuse on the same schedule. The interval between garbage collections should not exceed 10 days so that fly-breeding in the collection can is prevented. Daily collections from commercial properties is normal procedure, although it is also customary to make special charges for this extra service. Whatever the interval, it is important that the schedule be kept.

It is frequently desirable to require the householder to separate wastes prior to collection. When incineration is used as the final disposal method, segregation of ashes and non-combustibles from refuse and garbage is important. Separation of garbage from other wastes is necessary for hog feeding or reduction procedures. With disposal in a sanitary fill or dump, separation is not usually required and all refuse is collected together. In commercial areas garbage and refuse are generally separated from ashes and other trash.

Many cities require that garbage be wrapped in paper before being placed in the container. This is very satisfactory since it requires that the garbage be drained prior to wrapping and the containers are therefore kept cleaner. Wrapped garbage is objectionable for hog feeding and the reduction process, but acceptable for all other disposal methods. Lining of garbage pails with paper for wrapped or unwrapped garbage is widely practiced.

**Containers.** Metal containers with tight fitting lids are often required in cities for garbage and refuse containers. They should be water tight, fly-tight, easy to wash and keep clean and convenient to handle. Since the prevention of rodent feeding is one of the important reasons for proper garbage disposal, all containers should be proof against rodent entry. The size of the container varies with the type of refuse. A 10 gallon can for garbage is adequate for each family with semi-weekly collection and a 20 to 30 gallon can should be satisfactory for rubbish and ash containers. Oil drums should not be used because they are too large to handle easily when full.

Containers are usually furnished by the householder although in apartment houses the owner is frequently held responsible for providing them. Metal cans will last about 3 years, if kept clean with hot water and a detergent. Use of lysol or a similar disinfectant is good practice since it eliminates bad odors. The disinfectant must not be substituted for cleaning. Dirty garbage cans are prolific breeding places for flies.

**Collection.** Except where service charges are levied, quantity collection limitations are not widely applied to residential sections. In commercial zones various limits for free service are imposed such as "1 barrel, cubic yard, reasonable amount, or day by day accumulations."[7]

Alley refuse collection with the containers located at the property line is the most practical. Frequently alleys are too small to permit modern collection trucks to operate or they do not exist in newer parts of cities and curb collection must be used. Containers should be emptied directly into the trucks and replaced at the point of origin. To avoid unsightly streets, citizens should know the approximate time that the collection truck will come to their premises and they should be encouraged to put garbage and refuse out for collection shortly before that time and to remove the containers as quickly as possible thereafter.

The collectors are held responsible for not scattering any material during loading or after it has once been put into the truck. Brooms and shovels should be carried to remove anything that has been spilled. During windy days the trucks should be closed even during short trips between collection points and always closed when a load is taken to the point of final disposition.

Fredericksburg, Va., rents the cans to the patron. The filled can is replaced with a clean one by the collector. Refuse is incinerated and the cans are cleaned at the incinerator. Trucks carry special decks on the side to

FIG. 74. Obsolete type refuse collection truck

hold the empty clean cans.[4] Other cities have a similar arrangement. An ordinance in Baltimore, Md. requires that all cans be of metal and have tight lids, with a penalty for non-compliance. This is enforced by a "sanitary squad" of 20 men from the police department. The squad covers a given section of the city each day and has been a large factor in keeping the streets free of litter.

*Vehicles.* Collection equipment includes wagons, standard dump trucks, trailers, and specially developed enclosed bodies with "trimming" loading machinery. Trucks for refuse collection are used by 96 percent of the cities in the United States.[7] The basic principle in modern design is to prevent trash from spilling over the streets; to avoid physical strain by the col-

lectors in loading; to eliminate objectionable odors as the trucks move through the city; and to provide economical means for trucking.

The rear end dump truck with high sides and open top is obsolete since it is responsible for many hernia cases among the collectors. When this type of truck is used, the height of the sides should not exceed 4 feet 6 inches or a "shaker man" should ride in the truck to receive the cans and distribute their contents in the truck. A shaker man is essential if mechanical loading is not provided.


FIG. 75. Modern "packer" refuse collection truck

Refuse collection vehicles must be adapted in size and capacity to local conditions. Their capacity should permit collection of a certain number of full loads per 8 hour day by the crew assigned. Enclosed steel bodies are desirable and may be used for both refuse and ashes. One type in common use is equipped with rolling side doors to reduce the maximum lift by the collectors. This relatively low body type is useful for garbage where large capacity is not necessary in relation to cubical content. Several types of enclosed trucks are provided with mechanical devices for handling and compacting the material. This equipment makes possible a reasonably large capacity unit with low loading height.

The New York City model uses a screw conveyor to carry the refuse from an end hopper into the truck body. A new popular unit which loads and consolidates the refuse consists of a back loading compartment from which a mechanically operated gate sweeps the material into the truck. When the body becomes partially filled the gate plunger continues to push the refuse forward, compacting it.

Refuse collection trucks are equipped with hydraulic hoists and back end gates for the discharge of their contents. The plunger compacting trucks


FIG. 76. Removable bulk container refuse unit and chassis

are similarly equipped with the back converted to an end dump type by a manual locking device. Removable bulk container units to be carried on a chassis frame have been developed for the handling of refuse from markets and similar places. These units may be advantageously used where 6 to 8 cubic yards or more accumulate between collection periods.

Collection equipment must be cleaned with water under pressure at the end of each day. Cleaning after each load has been dumped is practiced in some cities. At weekly intervals the bodies should be scrubbed with a detergent and with steam under pressure to remove accumulated grease.

Collections by commercial enterprise under contract to the municipality have been successful in many instances. If the agreement is carefully drawn, and provides for specific services to be rendered, for a given fee,

and if the contract is awarded by open competitive bidding, the service furnished can be satisfactorily and efficiently conducted. Contracts should be for a minimum of 5 years and should include a bond for a reasonable sum to be collected by the city should the scavenger not meet the terms of his contract.

## REFUSE DISPOSAL

Incineration, hog feeding, sanitary fill and open dumps are the principal methods of refuse and garbage disposal. Hog feeding and the open dump are the "time honored" methods for disposal and at one time or another have been utilized by every municipality.

The methods of disposal reported in 1949 by 200 cities have been tabulated by the American Public Works Association.[10] This shows the following distribution:

| Population Group of City | No. of Cities Answering | Open Fill | Sanitary Fill | Incin-erator | Hog Feeding | Reduction |
|---|---|---|---|---|---|---|
| 500,000 and over | 12 | 1 | 8 | 8 | 5 | — |
| 100,000 to 500,000 | 30 | 2 | 17 | 14 | 11 | 3 |
| 50,000 to 100,000 | 21 | 4 | 9 | 7 | 7 | 1 |
| 25,000 to 50,000 | 23* | 5 | 9 | 7 | 11 | — |
| 10,000 to 25,000 | 41* | 9 | 15 | 12 | 12 | — |
| 5,000 to 10,000 | 73 | 38 | 14 | 7 | 17 | — |
| Total | 200 | 59 | 72 | 55 | 63 | 4 |

* One city grinds garbage and disposes of it in sewage treatment plants.

### Dumps

The dumping of garbage in isolated locations is widely used. It is commonly practiced where waste land is within a reasonable haulage distance. Open dumps are breeding places for rats and vermin, constitute a fire hazard with smoke and odor nuisance, and should not be tolerated. Disposal of ashes in swampy and low lying areas is satisfactory and does not create a nuisance.

The sorting of rubbish particularly on large dumps attracts a certain number of individuals who in some instances actually live in shacks on the dump. This situation is messy and a sanitary hazard since pickers scatter the garbage and refuse, making disposal unsatisfactory.

New York City for several years dumped garbage and refuse in the Atlantic Ocean beyond territorial waters. Seattle, Wash. has discharged similar material into Puget Sound since about 1890. The states of New Jersey and Connecticut brought suit in the Supreme Court against New York City in 1931 for an injunction restraining the City from dumping in the sea since great quantities of obnoxious material were cast upon the

beaches of the two states creating a nuisance and injury. This injunction was granted and the method of disposal was abandoned. The City now uses incineration and land fill.

### Reduction

Garbage is reduced by cooking it with steam in large kettles to obtain grease and cattle food products. After digestion the water is cooled in large vats from which the grease is skimmed, and extracted by filter presses or vacuum centrifuges. Additional grease is extracted from the filter cake by organic solvents. The cake, and in some instances, the residue from evaporation of the water are salable as tankage for fertilizer manufacture.

Reduction plants unless properly designed and efficiently operated produce objectionable odors from the digestion vats, requiring constant supervision. Unless the market price for grease is above normal, reduction processes are uneconomical. The plant at Indianapolis, Ind. reported in 1941 the production of 1,200,000 pounds of grease, 795 tons of cattle feed and 3000 tons of tankage from 30,000 tons of garbage. Washington, D. C. reported profitable grease sales from 20,000 tons of garbage during the war.[14] Many reduction plants have been abandoned as unprofitable to operate or as odor nuisances.

### Hog Feeding

Hog feeding has been carried on for years and persists in those locations where it has gained a foothold but it is generally true that there are not many new projects being undertaken. Counteracting all its advantages is the definite disadvantage that the most careful separation of materials is necessary since the hog must be fed on garbage from which all rubbish, tinware, glassware, and other deleterious material has been removed. In view of the fact that the household rubbish collection, combined with the street sweepings, is a problem of almost equal importance to garbage collection, the hog feeding solves only half the problem at best. Even with careful sorting of garbage, a large proportion is uneaten by the hogs. The portion uneaten must be disposed of in some fashion. The principal objection to feeding garbage to hogs is the high incidence of trichinosis infestation among such hogs.

Feeding of hogs should be under the control of the municipality and the size of the herd must be sufficient to consume the maximum quantity of summer garbage. A ton of garbage per day will be consumed by 100 animals including pigs and sows. This should provide enough food for each animal to gain in weight one pound a day. An acre of land will accommodate 50 hogs or 2 acres per ton per day of garbage is required.

Location of hog farms should be within reasonable haulage distance but

in isolated areas to prevent local nuisance and complaint. Usually the farm is about 5 to 10 miles from the contributing town. Conditions on hog farms can be made sanitary with well-designed feeding platforms, with water under pressure for cleaning, and with inedible wastes burned or buried, as at Los Angeles, Calif. and elsewhere.[16] However, too often hog farms degenerate into mud wallows with messy feeding troughs and subsequent bad odors, and consequent conflict with local nuisance laws.

The importance of the garbage-fed hog, as the source of human trichinosis, was reported by Mark[3] who in 1889 showed the relative importance of raw and incompletely cooked pork scraps in garbage as the important source of the parasite causing the disease. The common occurrence of these scraps in garbage and swill and the subsequent eating of them by large numbers of hogs are well estabished facts. The feeding to swine of such scraps constitutes "a dependable, large scale, year round source of trichinae for swine."

Since it has been definitely established that pork garbage scraps are the direct source of trichinosis in swine, all garbage fed to swine should be cooked to remove this danger. Recent experiments have shown that garbage must be boiled for 30 minutes in an open container to kill trichinae in pork particles 3 inches thick.[8] The United States Quarantine Regulations now require that garbage fed to hogs for interstate shipment must be boiled at 212°F. for 30 minutes.[19] Cooked garbage is a messy liquid gruel, difficult to handle, and has a high non-edible residue. Until vacuum or other drying processes are adapted to this problem, hog feeding with cooked garbage will not be popular.

In spite of the disadvantage of disposing of garbage by feeding it to hogs, a recent survey by the United States Public Health Service disclosed the fact that 52 percent of 763 cities having a population in excess of 10,000 feed garbage to hogs. It seems evident that "the situation today indicates that methods of garbage disposal have not kept pace with the marked improvement effected during recent years in other municipal sanitary services."[8]

## Sanitary Fill

This operation consists of dumping garbage, refuse and ashes in layers of controlled depth and width into trenches or depressions, and covering the fill promptly on all sides with a layer of clean dirt, sand, or similar material of sufficient thickness to exclude rodents and to prevent the escape of odors or outbreak of fires.

The sanitary fill procedure has been developed from those methods utilized at Seattle, Wash., since about 1915, and at San Francisco, Calif., since 1932, to reclaim low land or tide water marshes. Utilization of the

trench, cell, and cover method without compaction of the garbage was developed at Fresno, Calif. in 1935.[11] Land filling operations with garbage and refuse and the abandonment of 11 incinerators was undertaken by New York City in 1937 and created considerable local controversy, resulting in the indictment of the Sanitation and Health Commissioners for creating a nuisance.[12] This indictment was dismissed and the question referred to an arbitration board of nationally known health officials[13] who approved the use of sanitary fills under the following conditions:

"1. The disposal of wastes by the landfill method should be planned as an engineering project. Operation and maintenance should be under the direction of a sanitary engineer.

2. The face of the working fill should be kept as narrow as is consistent with proper operation of trucks and equipment in order that the area of waste material exposed during the operating day be minimal.

3. The exposed surface should be covered with earth as promptly as is consistent with proper operation and at the close of each day's operation both the surface and the face of the fill should be completely covered, the object being to make a closed cell of each day's deposit.

4. Sufficient standby equipment should be provided to prevent delay in covering, due to break down or peak loads.

5. Waste building material, concrete or other bulky waste material which may furnish rat harborage should not be used for the final surface or side slopes, but should be promptly incorporated within the fill.

6. The final covering for surface and side slopes should be maintained at a depth of approximately 24 inches.

7. In case the finished fill has a boundary side slope, the toe of the slope should terminate in a sand and gravel filled ditch. This will prevent raveling of the toe with exposure of some of the waste material, will prevent the burrowing of rodents, and finally will obviate puddles by permitting seepage from the fill to be absorbed into the ground.

8. Spraying of the exposed waste material and adjacent surfaces should be used when necessary to allay dust.

9. As a rule, the layer of refuse should not exceed an average depth of about 8 feet after compacting. When deeper fills are necessary the filling should be carried on in stages.

10. Control over the blowing of paper should be adequately maintained by the use of movable snow fencing.

11. While the maintenance of proper earth covering as hereinbefore recommended will to a large extent prevent fires, water under pressure should be available for fire fighting purposes. If scavengers are tolerated they should be adequately supervised.

12. All collections of surface water resulting from these landfill operations

should be drained, filled or treated with effective chemicals to prevent mosquito production or allay odors.

13. Where necessary, effective steps should be taken to prevent floatage of waste material into open water.

14. Inspection for and control of rodents should be maintained until the fills are stabilized.

15. After the active period of filling operation is completed a maintenance program should be continued until the fill has become stabilized so as to insure prompt repair of cracks, depressions and erosion of the surface and side slopes.

16. Studies of the varied problems involved in land fill operations should be continued and should include researches into the biological, chemical and physical activities, as well as the engineering, economic and administrative aspects."[22]

Advantages in the use of sanitary fills are the reclamation of waste land; the elimination of the need for segregation of rubbish components in garbage; and where not affected by long hauls, low costs of collection. When properly made these fills do not offer rodent harborage, are odorless, and present a minimal fire hazard.

Seven-tenths of an acre is required per year for each 10,000 population when the garbage and rubbish is compacted to a depth of 8 feet. Deep trenches do not compact uniformly and when used should be developed in stages allowing the initial fill to settle for several years before a second layer of material is added to it. The face of the fill at which dumping occurs should be kept as narrow as practicable. The top cover should have sufficient grade to provide surface drainage.

The face of the fill is extended outward each day by dumping and the material leveled off with a crawler tractor equipped with a "bull clam" shovel. Compacting is secured by passing this equipment back and forth over the fill and cover is obtained by scraping earth in place with the blade. Fill should be compacted at least one third of its original volume after dumping. Not less than 2 feet of cover should be placed on the top and sides of the fill, with at least one foot of cover on the face of the fill at the end of work each day. This prevents rat harborage since the rodents will not burrow more than 12 inches below the surface; it also provides sufficient depth to prevent serious cracks with subsequent escape of odors and methane and resultant fires. Temperatures in the fill rise to 130°F. to 150°F. in about 4 days at a depth of 3 feet, and remain high for 60 days. After about 10 or 12 months they gradually reduce to that of the surrounding earth.

Offensive conditions have been noted during excavations in old sanitary fills. Installation of utilities in a fill for a housing development in New York exposed undecomposed material and caused such a stench that

workmen left the job and nearby residents complained.[2] To avoid the possibility of fire the temporary houses built on the area were constructed with a vented air space beneath them and their floors were sealed with an aluminum foil membrane.[17] Such conditions are to be expected since it has been demonstrated that all organic materials may not decompose in fills and that when the sealed-in oxygen is used, decomposing action ceases. Excavations at San Francisco, Calif. have disclosed the presence of undecomposed leaves, citrus fruit rinds, paper, etc. after 10 years burial.[15]

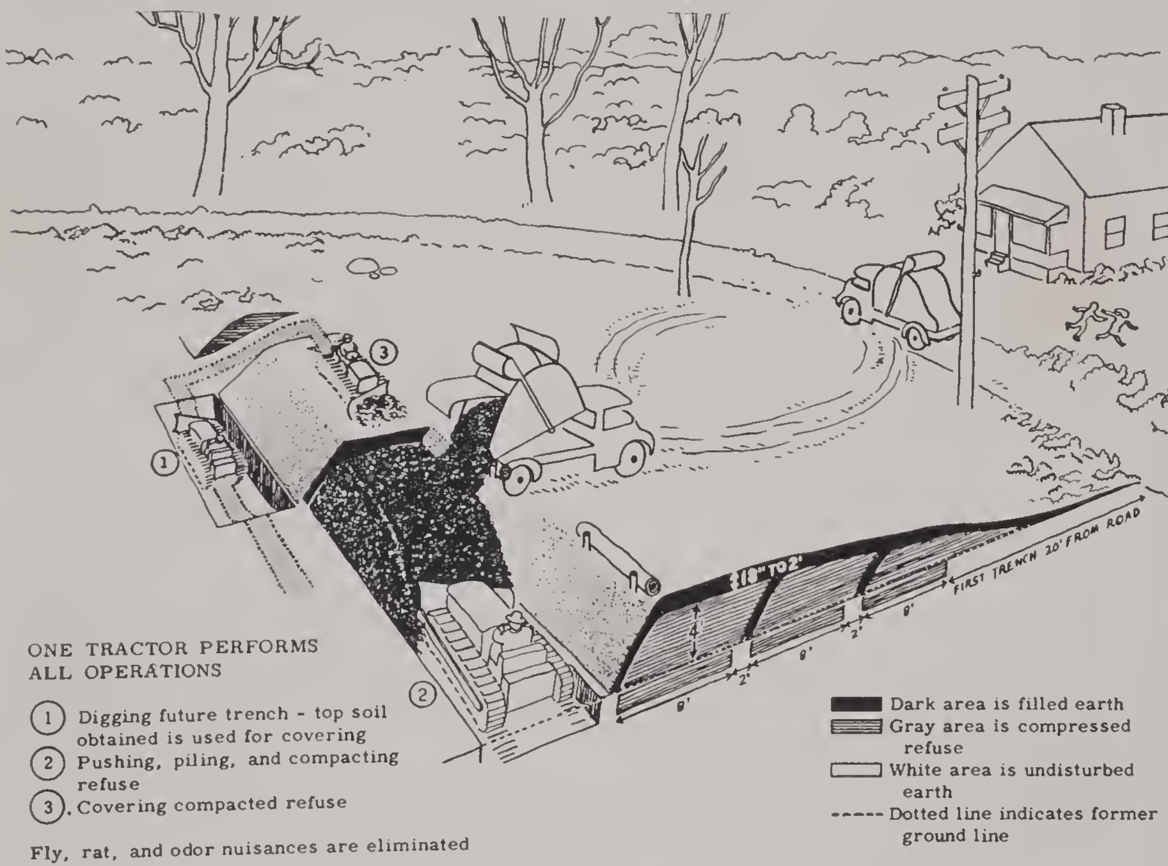


FIG. 77. Schematic view of a sanitary fill. (Courtesy, Clarence W. Klassen, Illinois Department of Public Health.)

Settlement of the fill area proceeds at a rate of one foot for each 5 feet depth of garbage and refuse in the first 6 months and an additional half foot after 2 to 4 years until stabilization is reached. After settlement is complete, fills may be grassed and used for parks and other recreational areas or for very light construction purposes.

Skilled supervision is necessary for the proper maintenance of a sanitary fill. Where considerable waste ground is available within reasonable haulage distance of the city, use of a sanitary fill is justified. It should not be considered for long range planning or as a permanent replacement for incinerators. The sanitary fill is not inexpensive so budgets should include allowances for equipment, labor, operation, and maintenance.

## Incineration

The purifying properties of fire extend to garbage disposal where incineration is one of the standard methods of treatment. There can be little doubt, considering technical factors, that it provides the most satisfactory method of disposal. The principal negative factor is its expense. Large cities, such as New York City, are reaching the point where vacant land areas available for sanitary fills are located farther and farther from the city centers of population. This means that the expense of hauling the loads of garbage and refuse to the land fill sites are such that financing of incinerators is able to compete with this normally cheaper method. Incineration does not eliminate all possible nuisance features from garbage disposal, but it is better from this viewpoint than any other method.

Changing habits of everyday living are reflected in the changing characteristics of garbage. The increase in the use of pre-packed frozen vegetables and fruits means that much of the garbage resulting from the preparation of these products is collected at the processing plant. Domestic waste has less garbage now than it had 10 years ago. This means a decrease in the volume and weight of household waste.

Likewise the widespread use of canned foods results in large quantities of empty containers appearing in garbage. In some areas 50 percent of the residue from incinerators consists of tin cans. This large volume of cans presents possible rodent nesting or mosquito breeding sites when they are discarded on the dumps. Crushing the cans reduces their volume by 85 percent—or the total residue by 40 percent.[10]

Incinerator capacity varies from 10 to 700 tons per 24 hour day. The incinerators are equipped with sufficient furnaces to operate at 150 percent of rated capacity for limited periods of time. Temperatures are kept between 1400°F. and 2000°F., and are not allowed to drop below 1200°F. Furnace capacity ranges from 5 to 250 tons of garbage. Occasionally auxiliary fuel, coal, wood or oil is used to maintain required temperatures. Figure 79.

The refuse receiving bin should have a capacity equal to an operating day and be located below grade of the driveway to permit the trucks to dump directly into it. A drain must be provided for the discharge of liquids, and water under pressure must be available for cleaning.

Garbage and refuse is placed on the charging floor or into the hoppers by crane operated clam shell buckets. A two-rail crane should be used wherever possible. Relatively high speeds for the elevating mechanism have been found economical. The crane system should be of sufficient capacity to lift all of the material that can be loaded into the furnace at one time.

One of the principal duties of a skillful incinerator crane operator is

proper "feeding" of the hoppers with a well balanced charge. In spite of the fact that garbage and rubbish are theoretically collected together, there

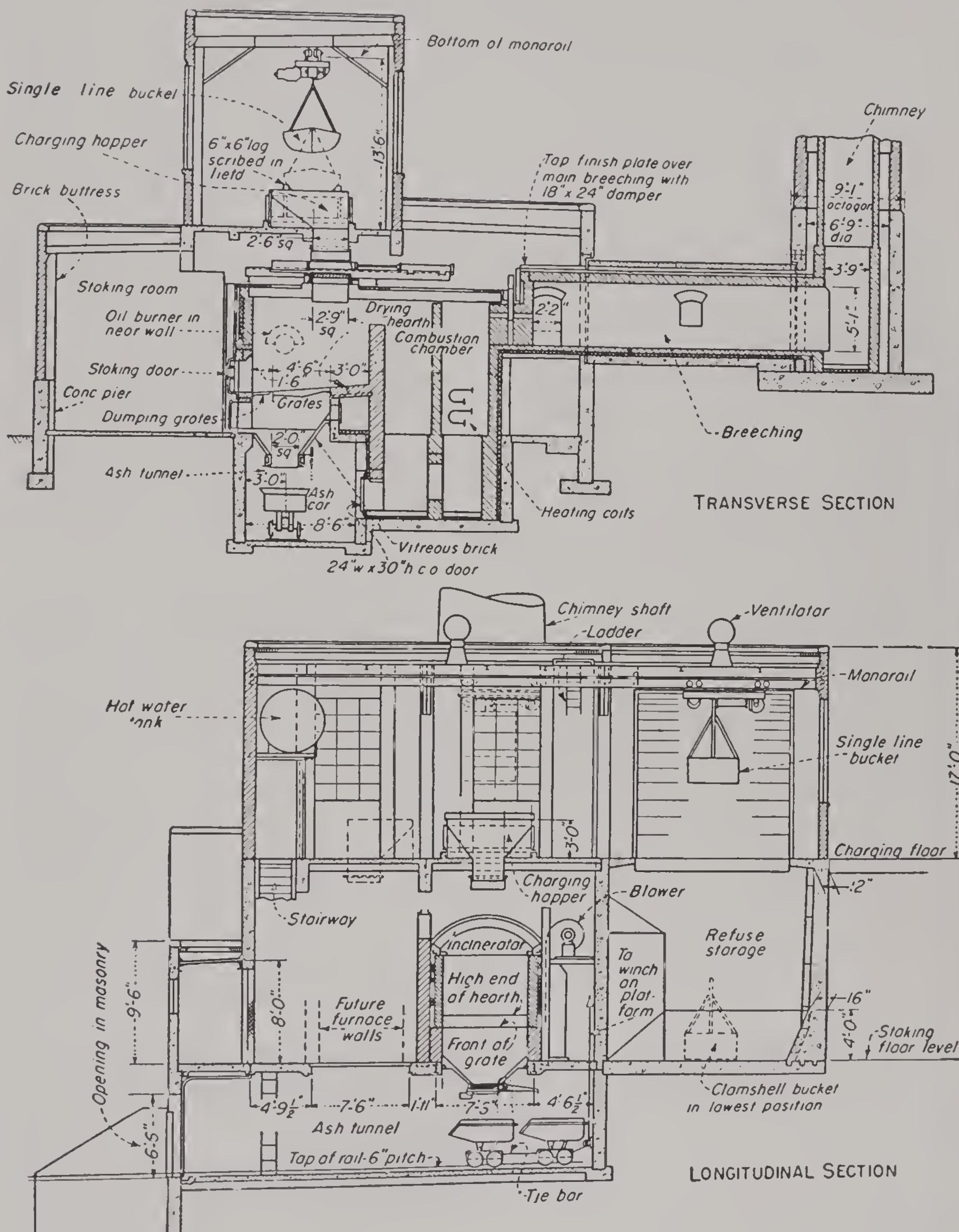


Fig. 78. Schematic section of an incinerator. (Courtesy, Henry W. Taylor and Engineering News Record.)

will be large masses of green vegetables or paper that will not be mixed uniformly in the delivered wastes. Two or three bucketsfull of fresh corn husks are sufficient to put out a hot fire or reduce it to a mere smolder. On the

other hand a constant feeding with newspaper and cardboard will generate a flame so hot that it will injure the brickwork, while at the same time fly ash will be emitted from the stack causing a nuisance at a considerable distance from the plant. The craneman, if he uses judgment, can furnish material which will keep the proper type of fire, while the furnaceman will receive with each hopper load, a selection of materials from which he can rake down onto the grate what is needed for the best results.

**Hoppers and Furnaces.** After the garbage and refuse have been delivered to the charging floor hopper men with long iron hoes manipulate

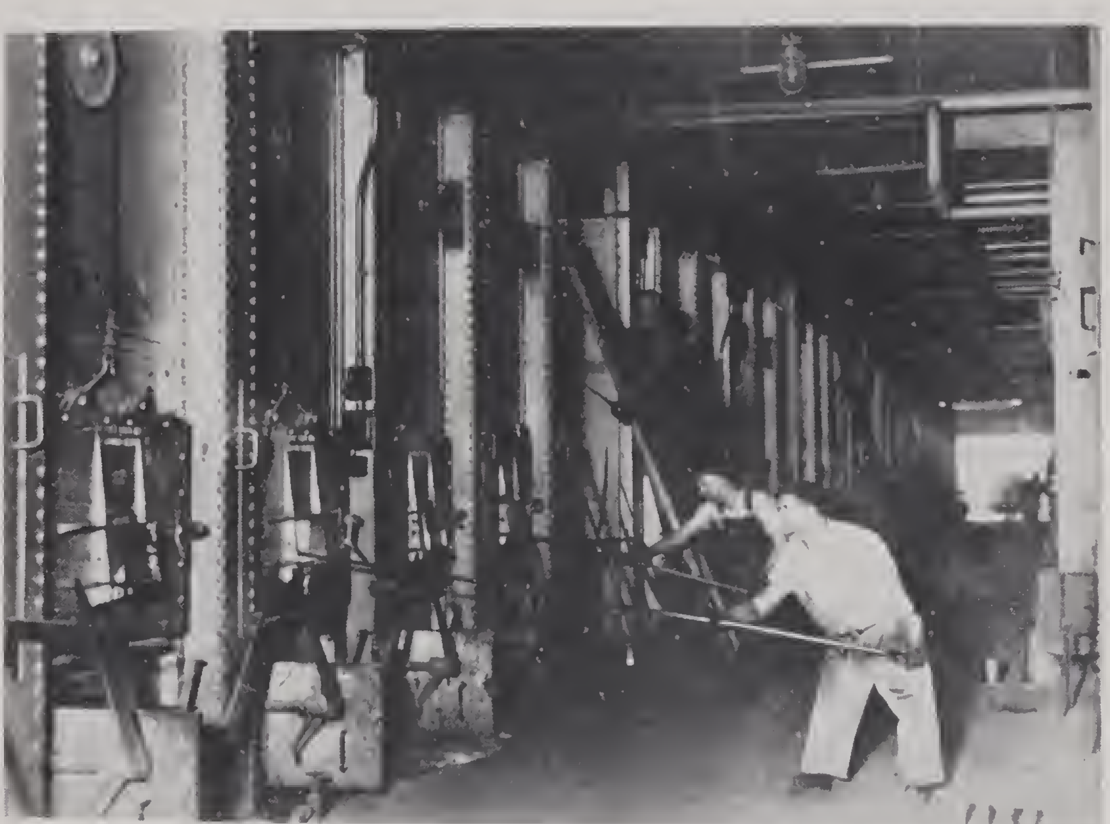

FIG. 79. Stoking a refuse incinerator

the refuse so that it does not get jammed at the narrow throat leading to the furnace. The hopper is separated from the furnace by a door which may be controlled either by the furnace stoker, the hopperman, or both. A satisfactory operation may be assured when the furnaceman, sometimes called fireman or stoker, controls the door by a suitable mechanism, electric or hydraulic, and permits as much material to fall into the fire box as can be burned at one time.

Furnace design is determined by the various manufacturers. There are however certain basic requirements that must be incorporated into them. Burning rates vary between 70 and 85 pounds of mixed refuse and garbage per square foot of grate area per hour, with combustion chamber capacity between 12 and 15 cubic feet per ton. To maintain high temperatures and

complete combustion, preheated air at 450°F. is passed under the grate. Fan capacity should provide air velocities of 25 to 30 feet per second and be capable of handling gas temperatures up to 1800°F.

In operation every effort is made to keep the temperatures between 1400°F. and 1800°F. to destroy the odors. Furnaces are equipped with recording pyrometers and temperature control is carefully maintained.

Fly ash (very fine solid particles from flue gases) may become a nuisance. It is caused by inadequate capacity, poor design, or by improper firing, principally by forcing the furnaces beyond their rated capacities.[6] Remedial measures consist of proper designing; operation within rated capacity; screening; baffling the gas flow; or jetting steam into the combustion chamber.

The question of the separation of household waste is a moot one when incineration is the method of disposal. Rubbish furnishes fuel for the incinerator and so aids in the disposal process. Tin cans are a blessing not unmixed with certain drawbacks; they take up room in the furnace but they also provide large openings in the waste mass, which give good air circulation to aid in the incineration. Magnetic separators can be used to remove the cans, but unless the sale price of the salvaged metal is high, this process is not economical. Furnace ashes also should be excluded; if admitted to the incinerator they may form a slag which will lead to a rapid deterioration of the combustion chamber.

Some provision must also be made for disposing of the ash residue. Unless the incinerator has been allowed to operate a great deal below normal temperatures there should be no organic or combustible material left in the ash. There may be considerable bulk and the possibility of rodent harborage should be considered in the final method of disposal. Mosquitoes may breed in any liquid waste that accumulates in containers in the residue. Land fill is the best method of disposal. This step must be carefully supervised or nuisances will result.

## Disposal of Garbage in Sewage Systems

This method of disposal was originated in Lebanon, Pa. in 1923 but later abandoned. It was revived in 1933 at Baltimore, Md. and given extensive publicity by Keefer.[5] The use of the city sewerage system for the disposal of excess garbage during the summer offered a means for experimentally determining its effect upon methods of operation at the sewage treatment works. This practical operation showed that garbage could be digested with the sewage sludge within 30 or 40 days. During the experiment garbage was fed into the sewer line at an average rate of 8 tons per hour with a normal sewage flow of about 80 million gallons per day. The period of study was for about 24 days.

The successful operation of the experiment led to studies elsewhere. Based upon these results, together with laboratory tests, Indianapolis, Ind.,[1] utilized this method of disposal in 1936 while the city reduction plant was out of commission.

As would be expected the oxygen-consumed value in the raw sewage plus the added ground garbage increased considerably but no unusual condition was found in the effluent of the primary settling tanks, and adequate digestion of solids was obtained. It was shown definitely by seven months' operation "that ground garbage offers no serious problem in sewage treatment and such disposition appears to be more economical than methods now in use."

Utilizing the published information from the more or less experimental study at Baltimore and the emergency operating data at Indianapolis, the City of St. Louis, Mo., on February 19, 1935, installed grinding plants for the disposal of its garbage into the trunk sewer which empties into the Mississippi River. Several other cities, including Lansing, Mich. and Gary, Ind.[12, 13] now use this procedure, discharging ground garbage into activated sludge plants equipped with separate sludge digestion.

The success of sewage plant digestion of garbage has led to the development of household grinders. These are now obtainable for attachment to any kitchen sink and are very satisfactory. It is estimated that over 50,000 units are now in service.[9] Introduction of these units, even on a large scale, has not yet seriously over-burdened adequate sewage treatment works, and from the information now available there is no indication that the ground garbage will clog household sewer lines. There is some indication that as these grinders become widespread older treatment works, particularly digestion tanks, may become overloaded. Kitchen grinders may sometime replace the garbage pail. Jasper, Ind. in the late winter of 1949–50 installed home grinder units on a city-wide basis. They are being substituted for community garbage collection and disposal. They were purchased in quantity by the municipality at low price and resold at cost to the property owner on the installment plan. Interest and maintenance cost equal $0.66 per family per month.[24] Since the city furnishes maintenance this expenditure may be charged off as equivalent to a tax for garbage collection and disposal. Grinders have been installed in 80 percent of the homes since enactment of the ordinance.[23] Future operation of the plan will be of interest from its economic possibilities and as a satisfactory community system of garbage disposal. This is of particular importance since neither rubbish or ashes can be included in the program.

## Conclusions

Disposal of garbage and refuse from built up city areas is one of the disadvantages of the modern conveniences of our present economic and social

life. Esthetics demands that this disposal be accomplished without unpleasant sights and odors. From a hygienic viewpoint, hazards to public health must be prevented. Rodent and fly-breeding and their attendant dangers are the chief factors to be guarded against. Garbage and refuse disposal requires careful supervision and adequate budgetary provisions.

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## Chapter X

# VENTILATION

Ventilation has sanitary significance because of the effect of air circulation upon the health and comfort of persons in restricted areas. Overheated room air which results in a reduction of ability to work is evidence of poor ventilation. The effects of inadequate ventilation are shown in several ways. They may be expressed in physical discomfort in which the ventilation is recognized as the principal cause: high or low temperatures, uncomfortable drafts, or high relative humidity are examples. The discomfort produced by odors, for which ventilation is not recognized as the causative factor, is another type. The expanding field of disease control by treatment of air illustrates a way in which ventilation demonstrates its importance from a public health and sanitation viewpoint. The discomfort produced by poorly ventilated rooms may arise from these several factors singly or in combination.

Rapidity of evaporation of perspiration with the corresponding cooling effect on the body is governed by the relative humidity. The odors in rooms occupied by excessive numbers of people arise from foul breath, unhealthy mucous membrane, dirty clothes, and other foreign sources.

No single method of ventilation is satisfactory under all conditions. From a practical viewpoint the criteria of satisfactory ventilation must be related to the specific conditions under question. A committee of the Industrial Hygiene Section, American Public Health Association has prepared the following list of desirable conditions that should be considered in planning systems of ventilation:[24]

*Outline of Working Standards for Atmospheric and Space Environments for the Maintenance of Health, Safety, Comfort and Efficiency*

1. A cool rather than hot atmosphere—but one without chilliness.
2. Dryness rather than dampness.
3. Still or moving air depending on physical activity of the occupants.
4. Some diversity in temperature—time and space—rather than uniformity and monotony.
5. Foot level as warm as head level.
6. Radiant, *i.e.*, local, heat source as an item in heating preferred.
7. Shockless temperature differentials between air conditioned quarters and outer air, depending upon the length of stay indoors, *i.e.*, less differential for brief stays.
8. Essentially noiseless conditioning apparatus.
9. Allotments of floor area. Air space and air supply should be sufficient

to fulfill physical, physiologic, epidemiologic and psychologic requirements of the occupants in any given enclosure.

10. Reduction of obnoxious dusts, bacteria, fumes, vapors, and gases to their sub-danger thresholds.
11. Satisfactory primary sensory impression upon entering the room or space.
12. Maintenance of comfortable conditions during occupancy (room comfort impression).
13. Sufficient replacement of "foul air" with "fresh air" to meet odor-comfort requirements. Filtering out of objectionable industrial odors.
14. Intelligent supervision.

These general goals are applicable to regulation of the atmosphere either in the home or in an industrial or commercial establishment.

In the past many theories were advanced to account for the ill effects of poor ventilation upon persons under crowded room conditions. For a long period of time it was believed that these physiological reactions were the result of an excess of carbon dioxide, but this theory has been proven erroneous. The survival of this belief until recent times, was due to von Pettenkofer's suggestion in 1863 that carbon dioxide concentrations be employed as the index of atmospheric pollution. The use of the carbon dioxide concentration test became so very general in ventilation studies that many persons regarded this gas, in concentrations found in restricted areas, as a harmful constituent of the air in such places.

Hermann in Holland about 1882 suggested that excessively high temperature and humidity were the causes of physical discomfort. It is now definitely known, due to the work of Flugge[8] in 1905, that the ill effects of poor ventilation are the results of conditions that influence the heat regulating mechanism of the body caused by relatively high temperature, high relative humidity and lack of air movement. Despite many investigations proving that carbon dioxide is *not* the controlling factor in ventilation, many ordinances and state laws require only sufficient ventilation for public buildings equivalent to 30 cubic feet of free air per person per minute. Since humidity, temperature, and air movement are the controlling factors, and not volume of air, these regulations are inadequate since their requirements may be either too high or too low with changing climatic conditions. The standard of 30 cubic feet per person per minute was originally based on the fact that the average person exhales 0.6 cubic foot of carbon dioxide per hour, from which six parts per 10,000 was fixed as the upper concentration limit.

## Definitions

Several terms of little meaning in general conversation are used frequently in discussions of ventilation. Following are definitions of some of these terms:[25]

**B.t.u.—British thermal unit.** This is the standard unit of quantity of heat. One B.t.u. is the quantity of heat required to raise the temperature of 1 pound of water 1 Fahrenheit degree. (This definition is presented as a practical definition and not one that includes all of the details of atmospheric pressure and specific temperature at which the measurement is made for theoretical purposes.)

**Comfort air-conditioning.** The process by which the temperature, moisture content, movement and quality of the air in enclosed spaces intended for human occupancy may be simultaneously maintained within required limits. This same definition would apply to comfort cooling.

**Comfort zone.** The range of effective temperatures over which the majority (50 percent or more) of adults feel comfortable.

**Humidity, absolute.** The weight of water vapor contained in a unit volume, pounds per cubic foot or grams per cubic centimeter.

**Humidity, relative.** The ratio of the actual quantity of water vapor in the air to the quantity that would give a saturated atmosphere under the conditions of temperature and pressure existing at the time of consideration. A saturated atmosphere has a relative humidity of 100 percent. Such a humidity would represent, at different temperatures, great differences in the absolute humidity.

**Psychrometric.** Pertaining to psychrometry or the state of the atmosphere with reference to moisture.

**Temperature, dry bulb.** The temperature of a gas or mixture of gases indicated by an accurate thermometer after correction for radiation. The dry bulb temperature does not make any allowance for the cooling effect of evaporation or for the different effect this cooling effect would have under conditions of differing relative humidity conditions.

**Temperature, effective.** An arbitrary index which combines into a single value the effect of temperature, humidity, and air movement on the sensation of warmth or cold felt by the human body. The numerical value is that of the temperature of still, saturated air which would induce an identical sensation.

**Temperature, wet bulb.** The temperature resulting from applying to the dry bulb temperature the cooling effect of evaporation under the relative humidity existing at the time. Thus, the wet bulb temperature will be the same as the dry bulb temperature only in saturated atmospheres because under those conditions, there would be no evaporation. The lower the relative humidity, the greater the difference between the wet and dry bulb temperatures because of the greater amount of evaporation possible.

## VENTILATION OF BUSINESS AND PUBLIC BUILDINGS

Public buildings are ventilated by open windows with or without deflectors, and by mechanically induced draft exhaust or pressure systems.

There appears to be no single normal temperature or humidity for comfort. A temperature of 68°F. with a relative humidity of 70 percent should be as comfortable as 73°F. at 20 percent relative humidity, with air movement of 15 to 25 feet per minute.

Mechanical roof exhaust fans are commonly found in large halls and auditoriums. Removal of the upper layers of heated light air causes fresh air to enter through windows, doors, ducts, or openings at the floor or other lower levels. Forced ventilation is well adapted to supplement natural

TABLE 23

*Fresh Air Requirements for Odor-free Atmosphere**

| | Room Space (Cu.ft. per Person) | Fresh Air (Cu.ft. per Minute per Person) |
|---|---|---|
| Private office or home | 1000 and over | 30 |
| General office | 500 to 700 | 15 |
| Conference room or game room | 250 to 300 | 30 |
| Average specialty store | 400 to 500 | 15 |
| Department store | 300 to 400 | 20 |
| Bargain basement | 200 to 250 | 25 |
| Restaurant (Quality) | 300 to 400 | 25 |
| Restaurant (Average) | 200 to 300 | 30 |
| Night club or bar and grill | 125 to 200 | 40 |
| Theater or auditorium | 200 to 300 | 15 |
| School (children) | 200 to 250 | 30 |
| " (adult) | 200 to 250 | 20 |
| Hospital—operating room | 1000 and over | 40 plus |
| " —private room | 750 and over | 25 |
| " —ward | 350 to 500 | 30 |
| " —public clinic | 200 to 300 | 35 |

* J. H. Bartol, Eng. News Rec., **105:** June, 35 (1950).

ventilation and when used for this purpose is usually accomplished by propeller fans. Pressure, or plenum, ventilation is the type furnished by motor driven fans, supplying air through duct lines under pressure, which is delivered to the room through specially designed and properly placed openings. In the operation of this system the incoming air may be washed to free it of dust and dirt particles, and to humidify it during the winter. It is then heated or cooled depending upon the season and outside temperature.

Table 23 gives estimates of room space per person and fresh air circulation, (cubic feet per minute per person) desirable for different types of room use.

For dormitories or barracks, 600 to 700 cubic feet of space per person

should be allowed for sleeping, with three changes of air per hour, which gives a supply of from 1800 to 2100 cubic feet per hour. For offices, theaters, etc. there should be 3000 cubic feet per hour, with five changes in this period, conforming to the 50 cubic feet per minute basis. In a room at normal temperature, a velocity of two feet per second is noticeable; four feet per second would cause a draft. If the incoming air is much colder than that of the room, air movement will be detected and objectionable drafts produced by much lower air velocities.

Fig. 80. Ultra violet irradiation of upper air to prevent product contamination and to protect personnel from respiratory infection. (Courtesy, General Electric Co.)

## STERILIZATION OF AIR

Control of air-borne infections from enclosed spaces such as assembly halls, school rooms, and barracks is under study.[6] Air-borne infections are believed to be transmitted by droplet nuclei and dust. Control of these infections has been attempted by mechanical ventilation, ultraviolet radiation, use of chemical mists, and dust retardation. It has been recently established by a committee of the American Public Health Association[17] that bacteriological criteria are not sufficient to show effectiveness of these procedures but they must be demonstrated by a "significant reduction in the incidence of disease in well controlled studies in human populations living under natural conditions."

Purification of air by forced ventilation including washing and filtration of air as practiced in air conditioning will only partially reduce the bacterial density in an occupied room since human activity maintains a con-

tinuous reinfection which is difficult to remove when only new air is circulated.

Ultraviolet radiation with a wave length of 2537° is effective when the relative humidity is not more than 60 percent.[4, 11, 22] To prevent danger to eyes and skin the direct action of these rays must be restricted to the air in the upper portion of the room. Present studies indicate that ultra-violet radiation is of value in special situations such as operating rooms, contagious disease wards and certain manufacturing operations but it has not been proven effective for general use in public assembly rooms.

Ozone is not suitable for use as an air disinfectant since a concentration of 1 ppm. may cause irritation of the nasal passages membranes. Concentrations greater than 1.0 ppm. are frequently necessary for bactericidal action.

Glycol vapors[19] are effective air bactericides when the relative humidity is between 30 and 55 percent. They are of value for general use since they are odorless, nontoxic, and noncorrosive to metals.[20] Concentrations of the magnitude of 0.2 ppm. have been effective with 67 percent relative humidity[10, 12, 18, 23] but the vapors were noticeable to persons occupying the room. Effectiveness improves with increases in temperature to at least 85°F.[10] Similar to ultra-violet radiation, these vapors are more effective against droplet nuclei than dust particles.[18] Properly vaporized, the glycol mists will permeate all parts of the room but maintenance of bactericidal concentrations throughout a room is difficult with present equipment. Studies in hospital wards and barracks have been undertaken but controlled data as to the effectiveness of these compounds have not been reported.

The application of a light paraffin or spindle oil to floors of barracks and hospital wards and the use of oiled sawdust for sweeping concrete floors has reduced the bacterial content of the air in these buildings.[21] Oil should be applied at the rate of 1 gallon per 200 square feet of soft wood flooring with a squeegee or hair broom. Soft wood floors so treated will retain dust for 8 months provided they are cleaned with hot water without using soap or powders. Only 1 gallon per 1,000 square feet should be applied to hardwood or linoleum covered floors. Heavier dosage will make them slippery. When oiled sawdust is used, 2 gallons of oil per 100 pounds of sawdust gives good absorption.[13]

Blankets and bedding impregnated with light oils[14] will retain dust and bacteria, preventing the liberation of the particles. By impregnation with an oil-water emulsion blankets will retain this property for considerable periods of time even though frequently washed.

Conclusive evidence has not been obtained to show that oiling of floors, blankets, etc. will prevent respiratory diseases. These practices do however reduce bacterial contamination in the air in barracks and wards.

Air disinfection is in the experimental stage. A recent review of the status of the control of air-borne infections concludes:[17]

1. The oiling of floors, blankets, and bedding has now developed to the point of practical application in the suppression of dust. Such measures constitute good housekeeping. They reduce bacterial contamination of the air, but there is as yet insufficient evidence that they prevent disease. Dust suppression should be applied wherever practicable in conjunction with ventilation, ultra-violet irradiation, and disinfectant vapors, when the latter methods are employed.

2. The available evidence strongly indicates that methods of air disinfection (ventilation, ultra-violet irradiation and glycol vapors) are useful adjuncts to aseptic techniques in the reduction or elimination of air-borne infections in operating rooms and in contagious disease and pediatric wards. Installations are indicated under conditions where there has been demonstrated or there exists potentially a significant incidence of cross-infection or a serious risk to patients. It is essential that competent engineering supervision be available to insure the adequacy of the original installation, to maintain its continued effectiveness, and to protect both personnel and patients.

3. It is not yet possible to compare the relative efficiency of ultra-violet irradiation and glycol vapors. Only the former method has been developed to a point of practical application. Recent designs of glycol vaporizers and automatic control devices give promise that adequately controlled studies may be conducted in the near future. The relative merits of the two procedures will involve such problems as cost, safety, and the consistency of effective operation based upon long experience.

4. The general use of ultra-violet irradiation or disinfectant vapors in schools, barracks, and in specialized industrial environments is not justified at the present time. There is great need for further carefully controlled field studies to define the mechanisms of the spread of infectious disease among these types of populations.

5. There is no justification for the indiscriminate use of ultra-violet light or other methods for disinfecting air in homes, offices, or places of public congregation.

## AIR CONDITIONING

Simple ventilation procedure has been superseded by modern air conditioning processes for public buildings, homes, stores, factories, and other industrial establishments. Mechanical means have been used intensively in industry for more than 40 years. Comfort conditioning of air did not become common until 1925 and then several years elapsed before its rise to popularity.

The "Guide"[25] published by the American Society of Heating and Ventilating Engineers defines air conditioning as "The simultaneous control of all, or at least the first three, of those factors affecting both the physical and chemical conditions of the atmosphere within any structure. These factors include temperature, humidity, motion, distribution, dust, bacteria, odors and toxic gases, most of which affect in greater or lesser degree human health or comfort." The scope of this definition is obviously limited to the effect upon "human health or comfort." To extend its scope to industry, it is necessary only to add the words "and the physical properties of materials."

The success of air conditioning depends upon accurate and reliable control. At least two effects must be obtained to allow true application of the term "air conditioning". These are change of air temperature and change of moisture content of the air together with regulation of at least one of them.

While a few instances are known in which the principle of evaporative cooling was used hundreds of years ago, air conditioning, in a crude form, had its birth in the textile mills of England. This country first gained its reputation for fine fabrics from the goods manufactured in small mills enjoying the equable climate of Lancashire. As the improvement of machinery began unfavorably to affect humidity in factories, the practice of sprinkling floors was started. As this proved inadequate, steam pots came into use and, much later, devices for finely atomizing water.

In 1897, Joseph McCready of Toledo, Ohio,[15] patented a washer for cleaning air. Following this, other types of washers were designed and were occasionally used for air cleaning in connection with ventilating systems. In 1906, Willis H. Carrier[3] discovered the relationship between quantity of saturated air supply and the magnitude of the internal heat gain. This discovery came as the result of the first application of an evaporative cooling system to a cotton mill. In 1907 Stuart W. Cramer of Charlotte, N. C.[5] automatically controlled the humidity by atomizing sprays of water with an instrument which depended upon the relation between the wet and dry bulb temperatures.

The measurement and control of the moisture content in textiles was then generally known in the trade as "conditioning," so that the term "air conditioning" seemed to apply quite logically to the methods which would maintain conditions having the desired effect upon the product.

Until 1911, all psychrometric tables and charts had been prepared from observed data. At that time, Carrier discovered and analyzed the physical laws relating to psychrometrics and presented his analysis before the American Society of Mechanical Engineers. Following this, there was a rapid development in applications to industrial plants. Starting with tex-

tile mills, it soon spread, until over two hundred different industries were utilizing some form of air regulation. It was not until 1925 that applications for human comfort became general. The first were made by theaters—followed rapidly by department stores, banks, restaurants, and, finally, by a few scattered residences of the luxurious type.

All of these installations both industrial and comfort cooling equipment, were of relatively large size and so built as "job shop" products. The development by Thomas Midgley, Jr. of a new series of refrigerants made available to the public in 1931,[16] resulted in a rapid utilization of the small refrigerating machine and accompanying air conditioning equipment, which could be standardized and manufactured in quantity production. This has lowered the cost of small installations and has broadened the field of application to all manner of small manufacturing and business establishments, and also to the home.

The atmospheric conditions which prevail in unconditioned spaces are governed primarily by the external absolute humidity and the internal heat gain. Both of these governing factors are variables. If conditions are to be kept constant at any predetermined point, the effect of these variables must be compensated for. This requires equipment capable of controlling the temperature by regulating the heat to be supplied or removed in accordance with the need. The equipment must also control the moisture content by raising or lowering the humidity as required and supplying an adequate volume of new air. The recirculated air must be cleansed of all foreign materials and properly admixed with the supply of fresh air.

The common methods of heating air are generally familiar. The usual steam, hot water, or hot air systems are examples. The heating load, commonly expressed in British thermal units (B.t.u.) per hour, is determined by the heat loss in outward transmission through the building structure and the infiltration losses or heat required to warm outside air that leaks in through cracks and crevices around windows and doors, or heat required to warm the outside air used for ventilation. Heat loss varies with the insulating value of the building, care and quality of construction, and with the temperature difference between the conditioned room and the surrounding space. Standard values are available for these different factors.

The cooling load, expressed in B.t.u. per hour or ton of refrigerating effect,* is governed by the heat transmitted from surrounding space to the conditioned room or absorbed from solar radiation, and by the amount given off from persons, lights, machinery, etc., in the room. Reduction of temperature may be accomplished by mechanical refrigeration or by evaporative cooling in which the outdoor air is drawn by a fan through water

* (One ton is considered as 12,000 B.t.u. per hour which is the cooling effect resulting from melting 2,000 pounds of ice in 24 hours at 32° F.)

sprays or over a wetted surface. Evaporative cooling may be combined with cooling by means of cool water from a natural source, or cool water may be used alone. The latter system is limited by the temperature of the water used, the minimum for the United States being between 50° F. and 60° F. when well water is used, and exceeding this value in other climates.

Another method of cooling, with ice, has a limited application due to its cost and the nuisance of handling the ice. Air may be passed directly over the ice but most frequently the ice is first converted into cold water and the air is passed through coils of the water. Obviously, cooling limits are above 32° F. and lower than those of well water.

Cooling with refrigeration is limited only by the limits of the machine. The liquefied refrigerant may be expanded directly into coils or used to cool water or brine. Refrigerant temperatures from 100° F. to below 0° F. are obtained for industrial processing; 40° F. to 50° F. are usual for general air conditioning; and 20° F. to 30° F. for food preservation.

A refrigerating machine does not "generate cold" but utilizes a volatile liquid or refrigerant at a low temperature to extract or absorb heat; it then conveys the heated refrigerant to a cooling area where the heat is released. The released heat must be carried away directly by air, as in the evaporative condenser; indirectly to air by means of recirculated water, as in the cooling tower (Figure 81); or directly by water of which from one gallon per minute at 65° F. to three gallons per minute at 85° F. is required for each ton of refrigerating effect. Both the evaporative condenser and the cooling tower save 90 percent of the water required for direct condensing use.

Cooling with vacuum evaporation created by steam ejection is also used. A steam ejector creates a partial vacuum in a chamber containing water. The vacuum causes part of the water to evaporate, cooling the remainder. The chilled water flows to the bottom of the evaporator and is pumped to the air conditioning system. The steam and water vapor from the primary condenser are removed by a secondary ejector or vacuum pump. This system has higher operating costs for large unit installations than does mechanical refrigeration.

A humid atmosphere can be uncomfortable even though the temperature may be low. Humidity can be reduced by passing the moist air over cold coils. The cooling effect causes condensation of the humidity on the coils. Dehydration may also be accomplished by adsorbing chemical materials, of which silica gel is an outstanding example. A silica gel unit, for dehumidifying air is composed of two adsorbers, a gas heated furnace, a ventilating fan for the adsorber, after cooler, fresh air filter, silica gel cooler, and control devices. One adsorber is in service dehydrating the air while the other is being reactivated by heat. The control of the adsorbers

and the reactivation is automatically regulated upon a time basis with electric clocks. The fresh air is taken from the filter to the adsorber where it is then mixed with circulated air, cooled, and passed out into the duct system. The proper adjustment of recirculated air and new fresh air will maintain the desired humidity and temperature.

The industrial application of air conditioning for the control of the tempering of products is one of the most important uses of this process. Aging

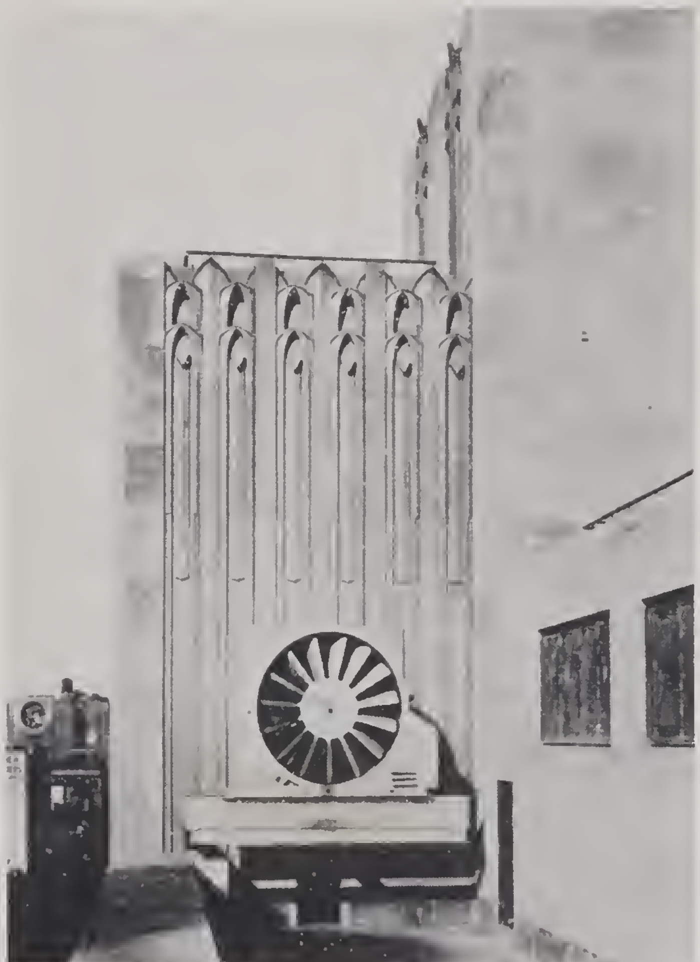

FIG. 81. Large forced draft water cooling tower in ornamental enclosure, Radio City, New York. (Courtesy, Carrier Corporation.)

of tobacco, machine manufacture of cigars, knitting of cotton and rayon thread are dependent upon its use. In the food industries the application of air conditioning to perishable products enhances their value. This may be illustrated by the use of air conditioning in candy stores to keep coca butter from depositing on chocolates with resultant reduced sales due to off color.

## Comfort Cooling

The distribution of conditioned air to the ultimate point of use is the most important factor of comfort cooling. In large installations it is accomplished

by the discharge of fan propelled air from direct systems. When ornamentation is desired these ducts are encased in the building walls and discharge the air through decorative grills. Comfort standards must be subdivided into consideration of conditions which are optimum for absolute comfort and conditions which are satisfactory for relative comfort. For many years, those experienced in air conditioning knew that a dry-bulb temperature did not indicate the true sensation of heat or cold, that might be produced by any specific temperature, and that relative humidity was an important factor. The definite relationship between the dry-bulb temperature and relative humidity of the atmosphere was not known until the Bureau of Research of the American Society of Heating and Ventilating Engineers embarked upon a vast program of research.[25]

*Effective Temperature*

One of the first accomplishments of the Bureau of Research was the determination of conditions of equal temperature sensation showing those combinations of temperature and humidity which to a human being would feel equally warm or cold or comfortable. The resultant effect of temperature, humidity, and air movement was termed the "effective temperature". Diagrams were prepared showing the effective temperatures determined through strictly subjective tests. These tests were applied further to determine the "comfort zone", as outlined on the psychrometric chart, Figure 82. This work is of inestimable value since it offers a unit of comfort measurement which can be definitely applied to normal human beings.

It is of utmost importance to note that the line which is optimum for summer comfort is higher than that for winter comfort, and that with the practically perfect conditioning system utilized in this research, there were always some test subjects in each hundred who were not completely satisfied with the condition which was considered optimum by the others. In other words, this means that no system can enjoy favorable reaction from all the people subjected to it. With an air movement of 15 to 25 feet per minute, 80 percent or more people are comfortable in the summer with effective temperatures of 68.5° F. to 73.3° F. and in the winter from 64.7° F. to 70.3° F.

It is interesting to note that the comfort zone is 1.0° F. higher for women than for men and that both women and men over 40 years of age prefer an effective temperature 1.0° F. higher than that of the younger group.[25]

Stale air is due to odors, smoke, etc. and not to a lack of oxygen.[1] Adequate ventilation is supported by introducing a requisite volume of fresh air, usually 25 percent, for the purpose of diluting odors, renewing the oxygen, and creating a slight internal pressure to oppose the inward leakage of unconditioned air. The supply of oxygen is rarely, if ever, a factor for

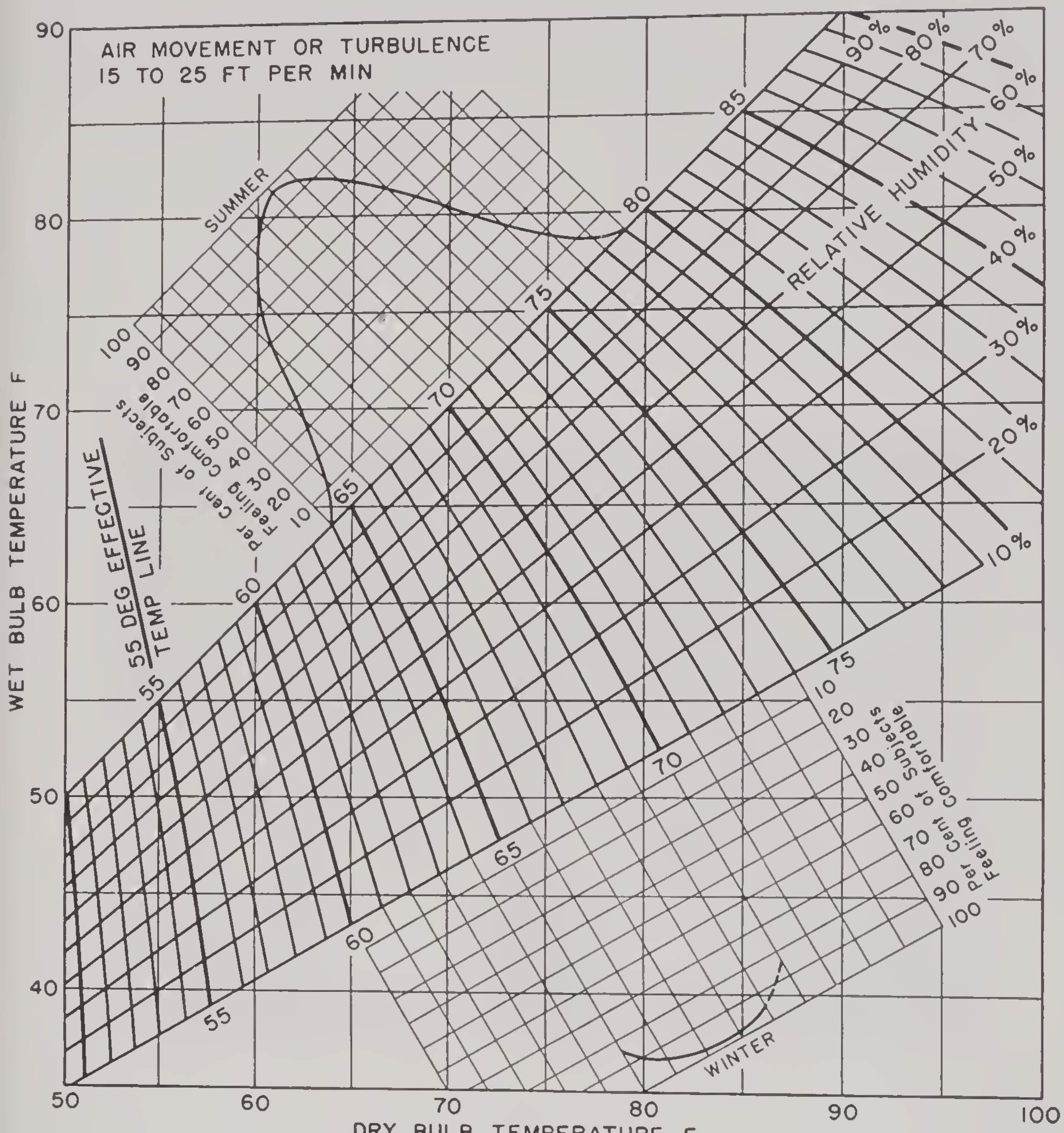


Fig. 82. Psychrometric comfort chart
A.S.H.V.E. Comfort Chart for Still Air

*Note.*—Both summer and winter comfort zones apply to inhabitants of the United States only. Application of winter comfort line is further limited to rooms heated by central station systems of the convection type. The line does not apply to rooms heated by radiant methods. Application of summer comfort line is limited to homes, offices and the like, where the occupants become fully adapted to the artificial air conditions. The line does not apply to theaters, department stores, and the like where the exposure is less than 3 hours. The optimum summer comfort line shown pertains to Pittsburgh and to other cities in the northern portion of the United States and Southern Canada, and at elevations not in excess of 1000 ft above sea level. An increase of one deg ET should be made approximately per 5 deg reduction in north latitude.

Dotted portion of winter comfort line was extrapolated beyond test data.

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consideration since outdoor air contains 21 percent oxygen by volume. Adults use 4 percent for breathing and 12 percent will support life; therefore recirculation of air is not harmful if the temperature, relative humidity, and bacterial content have not changed.

## Comfort Cooling of Railway Equipment

Cooling of railway cars began with yard cooling of coaches where ice was placed in compartments at the top and bottom of the cars and air circulated by fans through the ice compartments and cars. The first modern air conditioning equipment was installed, in July 1929, on the dining car "Martha

Fig. 83. Dining car "Martha Washington". (Courtesy, Baltimore and Ohio Railroad Co.)

Washington" by the Baltimore and Ohio Railroad. This was the first installation in a car in regular service and in 1931 this railroad operated the first completely air conditioned train in the world. From this initial development air conditioning has grown to its present popularity so that it is now an adjunct of railroad trains throughout the United States. Steam ejector evaporative mechanical compressor or ice compartment systems are commonly used for air cooling with a 25 percent makeup of fresh air in the air circulated. An advantage of the air conditioning of railroad trains is the installation of double windows which exclude dust as well as traffic noise.

## Comfort Cooling of Theaters

Air conditioning for comfort cooling of theaters is used in the main auditorium, lobby and lounge. Fans operating at 50 cubic feet per minute

per seat will give sufficient air change and justify their cost. Air conditioning for theaters should be based upon a temperature of 80° F. with a relative humidity of 50 to 55 percent. When it was initially installed some years ago 70° F. was maintained at all times. This lower temperature resulted in a chilling shock to many patrons and some complaints even now persist from remembrances of previous days, before proper control was instituted.

Because the average adult gives off 300 B.t.u. per hour, patron load is of importance in the relation of equipment design. An air volume change of 15 to 35 cubic feet per minute per seat, with a temperature difference from that of the outside air of not more than 20° F. is usual. From 5 to 7.5 cubic feet per minute of outside makeup air is used. The conditioned air is distributed through grills in the ceiling, side walls, and at the floor level baseboards.

### Comfort Cooling of Restaurants

In the air conditioning of restaurants two types are important. The high class restaurant, located in a hotel or similar place, has a peak load for about three hours in the early evening and is justified in maintaining complete equipment since its patrons desire the best in food, service and comfort and are willing to pay for it. A volume of 300 to 400 cubic feet per person is allowed in such a restaurant with a normal air change of about 25 cubic feet per person per minute. The second type of restaurant utilizing these installations is that in the shopping districts and in department stores, having a peak load of about three hours in the middle of the day. Its patrons will pay for a reasonable amount of extra service and comfort, but available space must be utilized to the maximum so that only 200 to 300 cubic feet per person are allowed. The restaurant occupying a separate building or a section of an office building can also only afford 200 to 300 cubic feet per person. Air circulation of 30 cubic feet per minute is required to maintain satisfactory conditions.

### Comfort Cooling of Offices and Homes

Living in a controlled atmosphere of a constant temperature and humidity is believed to increase individual efficiency. A report from a large Philadelphia, Pa., public utility corporation employing 500 persons, states that after air conditioning its office building, absenteeism decreased more than 50 percent. A controlled atmosphere, necessitating closed windows, provides a decrease in street noise and dust and permits a greater concentration of people per square foot of floor space without poor atmospheric conditions.

Air conditioning is being employed for hospital use and for the control of allergic diseases. The development of the portable individual room machine for the home has extended the use by hay fever sufferers of air con-

ditioners. One advertiser states that a conditioner of this type reduced the pollen count in a room from 1050 per square centimeter to 5 per square centimeter in 6 hours. Small separate room units are inserted in a window, are self-contained, use refrigeration and are not connected to water and sewer lines. They give good humidity and temperature control for small rooms.

The recirculated air in air conditioning systems is cleaned to remove dust, lint, pollen, odors, and smoke. The air is washed with water sprays or passed over oil covered deflecting surfaces. Soluble gases must be absorbed in water. Smoke particles are reduced in concentration by dilution with fresh air.

Experimental work is in progress using ultra-violet radiation, glycol mists, and other agents in air conditioning systems to kill bacteria and molds. Experiments have not been sufficiently conclusive to justify the general use of these agents.

## Effects on Water and Sewage Systems

A disturbing feature of widespread air conditioning is the effect upon the water supply and sewage disposal systems of a community. Many air conditioners use water in the process. This increases the water demand and also the sewage load if waste water is discharged to the sewer. Many cities regulate the amount of water that may be withdrawn through private wells to be used for air conditioning. Some cities have been compelled to prohibit the use of water from the city supply for this purpose.

An example of the amount of water demanded for air conditioning will show the magnitude of the supply problem. Water use for air conditioning in the Chicago Loop district has ranged from a low of 22 percent of the daily water consumption to a high of 50 percent.[9]

Water used for condenser cooling may have become contaminated and so should not be returned to the water distribution system. In addition there should be a 4 inch air gap between the end of the condenser discharge line and the sewer line to prevent back siphonage that might otherwise occur if the water discharge line were connected directly to the sewer and a partial vacuum should occur in the cooling system. Spray washer water must be recirculated in a separate system with makeup water from the potable supply introduced by overhead lines discharging into a tank with an air gap.

Table 24 presents data[2] which indicate the demand placed upon a water distribution system when conservation of air conditioning process water is not practiced. The increased demand is frequently reflected in the need for additional sources of water as well as increased treatment and distribution

facilities. Conservation methods can reduce the amount of water used from 2.5 gallons per minute per ton of refrigeration to 0.05 gallons.

The disposal of cooling water has become a problem in many cities. Miami, Fla., Jacksonville, Fla., Reno, Nev., Pasadena, Calif., and Wichita, Kan.[7] have restricted the discharge of water from air conditioning equipment to prevent overloading of sewerage systems. Some cities and state water conservation boards require the return of cooling water to water-bearing strata in the ground.

Regulation of water use for air conditioning is being given serious consideration. New York City and Philadelphia have adopted rigid control measures. The New York regulation restricts use of water to 5 gpm. while the Philadelphia rule established a limit of 74.5 gpm. Detroit, Mich., Newark, N. J., and Pittsburgh, Pa. restrict water use only when the distribution system becomes overloaded.

TABLE 24

*Water Used for Air Conditioning**

| | Theaters | Restaurants | Office Bldgs. and Department Stores | Separate Office Buildings | Speciality Shops |
|---|---|---|---|---|---|
| Demand hours per day | 7.3 | 8.8 | 7.1 | 6.5 | 5.5 |
| Percent of 24 hours | 30.4 | 36.7 | 29.6 | 27.1 | 22.9 |
| Gals. water required per ton refrigeration with conservation | 21.9 | 26.4 | 21.3 | 19.5 | 16.5 |
| Gals. water required per ton refrigeration without conservation | 1,095 | 1,320 | 1,065 | 975 | 825 |

* Ellwood L. Bean, J. Amer. Water Wks. Assoc., **40:** 313 (1948).

## VEHICULAR TUNNELS

Methods generally used for ventilating railroad tunnels by blowing fresh air from one portal to the other are inadequate to remove automobile exhaust fumes from long vehicular tunnels.

Railroad and motor vehicle tunnels present interesting problems in ventilation and demonstrate the strides that have been taken in solving intricate ventilation demands. Investigations of exhaust gas concentrations and other ventilation factors by the Bureau of Mines produced data that made possible the construction of the Liberty Tunnels at Pittsburgh, Pa. in 1924 and later of the Holland Tunnel in New York. These investigations established a limit of 4 parts of carbon monoxide in 10,000 parts of air, provided the exposure did not exceed 1 hour. They also disclosed that ex-

haust gases from automobile engines did not contain poisonous substances other than carbon monoxide. With this information in hand it was then possible to show the feasibility of building mechanically ventilated tunnels.

The Holland Tunnel, 8,368 feet long, is designed to carry 7,600 vehicles per hour, requiring 3,760,000 cubic feet of fresh air per minute or 42 air

FIG. 84. Governor's Island ventilation building, Brooklyn-Battery Tunnel. (Courtesy, The Triborough Bridge and Tunnel Authority.)

changes per hour. This air is supplied to the tubes through stacks situated on each shore, and is passed through numerous ducts by a battery of 84 fans. The fresh air duct is located below the roadway and the exhaust air duct above the ceiling with conduits and fans independent of each other. A peak load of 2,287 passenger cars in the tubes produced a carbon monoxide concentration of only 1.59 parts per 10,000 showing efficient ventilation.

A critical test of the ventilating system in these tunnels occurred on May 13, 1949, when 4,400 gallons of carbon disulfide exploded and burned

23 vehicles about 1,900 feet from the New Jersey portal. The fresh air system was promptly increased to 200 percent of normal but power failure put 2 of the 3 fans in the New Jersey shaft building out of service after about 60 minutes. During the resultant 5 hour fire, the exhaust system continued to function although the top duct failed for a distance of 500 feet.

Other motor vehicles tunnels of more than passing interest are:

The Posey tube, a single tunnel, 3,545 feet long, connecting Oakland and Alameda, Calif.

The Detroit-Windsor Tunnel, 5,135 feet long, with a ventilation system similar to that of the Holland Tunnel.

The Lincoln Tunnel between Weehawken, N. J. and New York City, which needs 8,834,000 cubic feet of air per hour for ventilation.

The Manhattan to Brooklyn Tunnel (New York City) completed in 1950.

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## Chapter XI

# SWIMMING POOLS

The swimming pool of today probably originated in the public baths of Greece and Rome. After the fall of Rome the baths became extinct until the seventeenth and eighteenth centuries. Legal authority was given for the construction of public bath houses by England in 1846. Other countries promptly followed suit, but the movement did not develop in the United States until 1891.

The design, construction, and operation of swimming pools is recognized as an important part of sanitation and the protection of public health. The public has been educated to the importance of proper treatment of drinking water and, though a few years ago almost any kind of water was acceptable, the supply must now be attractive to the eye, pleasant to the taste, and entirely free from dangerous bacteria. These requirements have spread to the swimming pool, and water meeting potable standards is now required by the citizens of the community for the protection of general health. The increasing use of pools for recreational and athletic purposes by a sanitation-minded public has brought about the demand that swimming pool control take its place with other sanitation activities.

The increase in popularity of swimming pools has resulted in their installation in many hotels, apartment houses, and schools. Recreation centers and public parks are considered incomplete without pools, and cities provide them in various parts of the community for the use of adults as well as children. With modern design and sanitary control, the danger of disease transmission is minimized and the recreational benefits can be exploited without reservation. However, hygienic control must be constantly and thoroughly maintained or swimming pools may become sources of danger to the health of the community, creating hazards that will overshadow the benefits they offer.

The danger of disease transmission through swimming pools has been argued pro and con. Suspicion has been directed to skin and eye infections, boils, conjunctivitis, and impetigo. Athlete's foot is considered to be one of the natural hazards of public bathing pools. It is conceivable that dirty towels and bathing suits passed from person to person without adequate washing might spread some skin and other infections. There is danger of athlete's foot but it probably is not greater at swimming pools than it is at any common shower. No good evidence has been presented to show the relationship of swimming pools to the transmission of any of the intestinal

diseases. Swimming pools have been suspected as a means for the spread of poliomyelitis, but there is no convincing evidence.

It is true that circumstantial evidence can be presented. Water is a good transmitting agency for certain disease organisms. Undoubtedly, some persons using pools may harbor various disease organisms, either as carriers or as unrecognized cases of the disease. With good operation swimming pools apparently are not a potent means for spreading communicable diseases. The chief danger seems to come from infectious material discharged from persons in close association in the pool rather than from generally contaminated water. Most swimmers drink very little of the water in which they swim.

The conditions in natural bathing waters where chlorination is not practiced are a different circumstance. But even under these conditions no authentic record of communicable disease transmission has been reported. Water polluted with sewage does seem to be dangerous for swimming. "Swimmer's itch" is common in some parts of the United States. This is caused by the free swimming larval stage of certain parasitic worms of the family *Schistosomatidea*. Waters in Michigan and Wisconsin have been infested with these organisms.

## TYPES OF ARTIFICIAL POOLS

Artificial swimming pools can be divided into three classes, deriving their identifying type from the method used to control the quality of water in the pool. The fill-and-draw type, as its name implies, is completely emptied and refilled with new water at certain intervals, the periods being determined by the physical appearance of the water or by the bathing load. This type is the least desirable.

A second type is the flow-through which uses a continuous passage of water through the pool at all times. A well-controlled residual chlorine content is possible in this pool and a safe water can be maintained. The flow-through pool treated thus can accommodate the same number of persons as specified for the recirculating type. The large quantities of water required usually make this method economically undesirable.

The third and preferred type is the recirculating pool, in which pumps remove the water from one part of the pool and return it to another after treatment to remove impurities which have been acquired through use. Usually this treatment involves filtration and sterilization. Pressure filters are generally used to permit purification by one pumping operation, although the installation of gravity filters is advised for larger units for economic and efficient operation. Diatomaceous filters are being installed in connection with new pools.

## CONSTRUCTION

It is obvious that pools should be constructed of impervious materials. The bottom and walls should be white or of a light color and as smooth as possible to facilitate cleaning. Plate steel tanks have been used successfully. Water depth should vary from 3 feet to at least 6 feet in the deep portions, with changes in depth occurring gradually. Surface area is based on 27 square feet per person at maximum load on the assumption that one third of the people patronizing the pool at any one time will be on shore. The pool length should be at least 60 feet and divisible by 15. The width should be at least 20 feet and divisible by 5 or whatever lane width is required in the locality for swimming competition. These requirements are specified so that the pool may be used for official races and other contests. The height of the diving boards and required depths and surface areas necessary for safe use must also be given study.

Water inlets should be spaced around the periphery of the pool to provide uniform distribution of water. About 50 percent of the recirculated water should enter the shallow section and outlets should be located in the bottom at the deepest section to facilitate good circulation through the pool. Pipe outlets must be protected by a grating having an area at least 4 times that of the cross section of the drain pipe to reduce suction currents. Drain lines to the sewer must have an air gap between the lines and the sewer to prevent direct cross connections. Connections for "make up" water from the municipal water supply should not be made directly to the pool recirculating system nor should they enter the pool below the high-water line of the pool so that possible back-siphonage from the pool into the potable water system can be avoided. Overflow gutters should extend completely around the pool and be designed so that debris caught in them will not be washed back into the pool by water movement.

Walkways should be constructed with a non-slip finish and a curb 1 foot wide and 6 inches high should be placed around the pool edge to prevent surface drainage or wash water from entering the pool. Water for pools should not be heated artificially above 78° F. in order to prevent optimum temperatures for pathogenic organisms.

## BATHER LOADS

The most recent standards[2] prescribe that when a fill and draw pool is used the total number of persons using it between changes of water should not exceed 1 per 500 gallon capacity of the pool. Flow-through pools without disinfection are limited to 1 person per 500 gallons of new water added. If continuous disinfection is used the permissible swimmer load is increased but the exact extent depends upon the bacteriological conditions prevailing

in the water. One investigator has suggested a maximum load at any time of one person per 35 to 45 square feet of pool area. Recirculating pools equipped with filtration systems which constantly maintain a residual of available chlorine of 0.4 to 0.6 ppm. or its equivalent have no maximum limit on the number that may bathe before the pool is drained and refilled. The maximum number of bathers at any one time should not exceed one per 35 to 45 square feet of pool area. As long as bacteriological and physical characteristics of the water remain satisfactory there is no need to restrict the number of persons who use the pool in any one day. This presupposes that the circulation system will be operated at a rate to give at least 3 turnovers of the pool contents in 24 hours and that chlorine is maintained at an available residual of 0.4 to 0.6 ppm.

## LOCKER ROOMS

Locker room sanitation is a very important part of swimming pool design and operation for the danger of infection especially of foot diseases is a great hazard. The floors should be smooth and well drained to facilitate frequent washing. All furniture, lockers, and other equipment should be of metal to permit effective cleaning. Proper ventilation is important especially in the case of indoor pools and the patrons should be protected from unnecessary or excessive drafts of cold air. Open air courts for dressing and undressing are desirable where patrons will accept them.

The sanitary protection of a swimming pool and its patrons can be greatly enhanced by capable alert locker room attendants. All bathers should be required to take a cleansing soap shower in the nude before putting on a bathing suit and an attendant stationed at the showers should observe the prospective bathers for indications of disease or illness which might prove a menace to others in the pool. Warm water should be provided for shower baths wherever possible so that the cleansing bath may be fully effective. With cold water the bather frequently does little more than run through the spray because of the discomfort of the chilly water. Water for showers should be taken from an outside source of supply; the use of pool water for showers should not be permitted.

The locker room floors should be washed daily and treated with a sterilizing chemical, such as a 0.3 to 0.6 percent solution of available chlorine, to prevent the spread of foot infections or athlete's foot. Wet floors provide a very favorable medium for the spread of this disease so good ventilation in bathhouses is desirable. The use of foot baths to control athlete's foot does not have practical value. Daily scrubbing and disinfection of shower and bathhouse floors are more important factors in preventing the spread of this infection.

Adequate toilet facilities conveniently located are a necessity. One toilet

## ALL PATRONS ARE SUBJECT TO THE FOLLOWING RULES AND REGULATIONS:

1. All persons must take a cleansing shower-bath in the nude, using soap and thoroughly rinse off all soap suds before putting on bathing suit.
2. All bathers should use the toilets and particularly empty the bladder before taking the cleansing bath.

### DO NOT URINATE IN THE POOLS

3. Any person having any skin disease, sore or inflamed eyes, cold, nasal or ear discharges, or any communicable disease will be prohibited from using the pools.
4. Spitting, spouting of water or blowing the nose in the pools is strictly prohibited.
5. Eating permitted at refreshment stand only.
6. Walk upright and do not run or crouch when passing through the showers at entrance to the pool enclosure or sand beach showers.
7. Chasing each other around the sand beach or pool deck permitted unless too violent.
8. No newspapers or pool towels are to be carried out on the sand beach.

Fig. 85a. Suggested swimming pool rules and regulations.

for every 40 women and one toilet and one urinal for every 60 men is the minimum. A shower for every 40 persons, based upon maximum pool load, is adequate.

Suggestions for patrons should be posted in conspicuous places in the locker rooms and also on the pool deck reminding them that their cooperation is necessary for the proper control of the pool for their maximum protection. Suggested sanitary rules to be included in a poster are shown in


FIG. 85b. Interior swimming pool, Hill School, Pottstown, Pa. (Courtesy, Roberts Filter Manufacturing Co.)

Figure 85a. The guards as well as the locker room attendants should enforce the regulations.

## SUITS AND TOWELS

The proper care of suits and towels, when these are provided by the management, is an important factor in swimming pool operation. Since both towels and suits come in close contact with the swimmer's body, discharges from one person may be carried to another if suitable cleansing and bactericidal treatment is not given between uses. The spread of skin disease can be prevented by cleansing and sterilizing these articles each time they are used. Dirty bathing suits impose an additional pollution load on the pool water.

The management of many pools finds it more economical to have towels cleaned by an outside laundry service, but this operation can easily be accomplished in the pool laundry where the suits are treated. Satisfactory disinfection can be obtained without bleaching colored suits by using quaternary ammonium compounds in 1:1000 dilution after washing with hot water and soap.

The use of swimming suits of all wool type should be discouraged and suits of all cotton or of a low percentage of wool substituted to permit proper washing in hot water without causing danger to the fabrics.

## SAND BEACHES

Many out-door pools are now constructed with a sand beach, a basic part of the bathing facilities, on which the bathers sun themselves. These beaches should be separated from the pool by a fence. Persons using the beach area should be required to take a shower before re-entering the pool to prevent sand from being carried into the pool on the suits of the bathers. Sand beaches should be raked daily to remove debris.

## WATER PURIFICATION FOR RECIRCULATING POOLS

The water in a recirculating pool should be recirculated at a rate to give one complete change of water at least every 8 hours. During this recirculation the water should be disinfected and passed through filters to remove dirt and turbidity.

### Water Treatment

The water leaving the pool first passes through a hair strainer in which hair, lint, rubber particles from bathing caps and shoes, and other foreign matter which might clog the impellers of the pump or filter beds are removed. Next, the water passes through filters for clarification. If sand filters are used, alum must be added prior to filtration to form a floc that coats the top of the sand bed—the same procedure as used in the treatment of drinking water. An average dose of 0.5 ppm. is effective. The purification principles are similar to those for a drinking water supply. Soda ash is applied to maintain the pH of the water between 7.2 and 7.6. This alkalinity will prevent eye-smarting when chlorine is used for disinfection.

Filtration equipment must have sufficient capacity to purify the total volume of pool water every 8 hours. The recirculating pump, of similar capacity, takes suction directly from the pool and discharges into the filters. Standard pressure filters are generally used (page 151). A filter rate of 3 gallons per square foot per minute is satisfactory with a back wash rate of 12 gallons per square foot per minute. Filters must be washed when a differential of 5 pounds is noted between the gauge on the influent and

the effluent lines. Regardless of minimum pressure loss, filters should be back washed every day.

The new compact diatomaceous earth filter using a silica "filter aid" and operating under pressure is satisfactory for swimming pool water purification. Its economical use depends upon cheaper operating costs. The space required leaves more space for other purposes and reduces construction costs. Preliminary treatment of water with a coagulant is unnecessary which decreases treatment cost and makes operation easier. The amount of water required for backwashing diatomaceous earth filters is much less than that required for sand filters. This gives further saving in time and money.

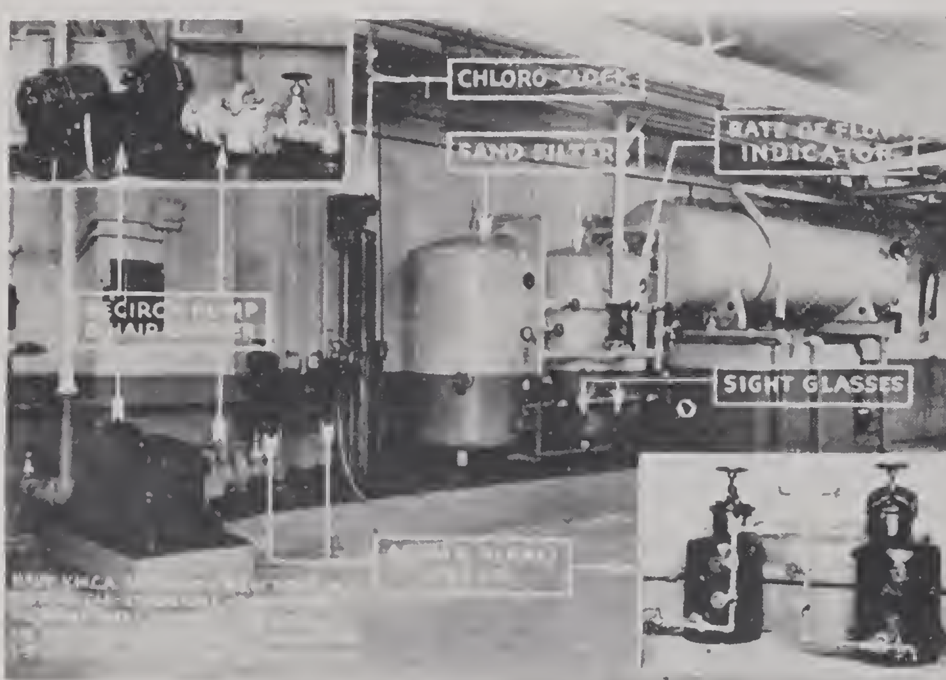


FIG. 86. Typical recirculating filtration system. (Courtesy, William B. Scaife Sons, Co.)

## Disinfection

Chlorine is the chemical usually used for the bactericidal treatment of swimming pool water. Bromine is used in some states but its use is not permitted in others.

Chlorine may be added as a gas using chlorinators similar to those in water treatment plants. Since the treatment of the water is important as a disease preventive measure, this type of chlorinating equipment is desirable wherever the size of the pool will permit the investment of the money required for equipment. A simpler method of applying the chlorine is in a solution obtained from calcium hypochlorite or sodium hypochlorite, using a simple displacement pump to force the solution into the recirculation water. A strong solution of chlorine, usually about 2 percent, is prepared in an

earthenware crock or rubber lined tank by using the proper amount of high test calcium hypochlorite. Aqueous solutions of sodium hypochlorite can also be purchased on the market. The displacement pump is regulated to give an amount of the solution sufficient to maintain the desired chlorine residual in the pool water. Addition of the chlorine should be continuous, not spasmodic.

Since the pH of the water has an important bearing on the activity of the chlorine as a bactericide and also on prevention of eye smarting appara-

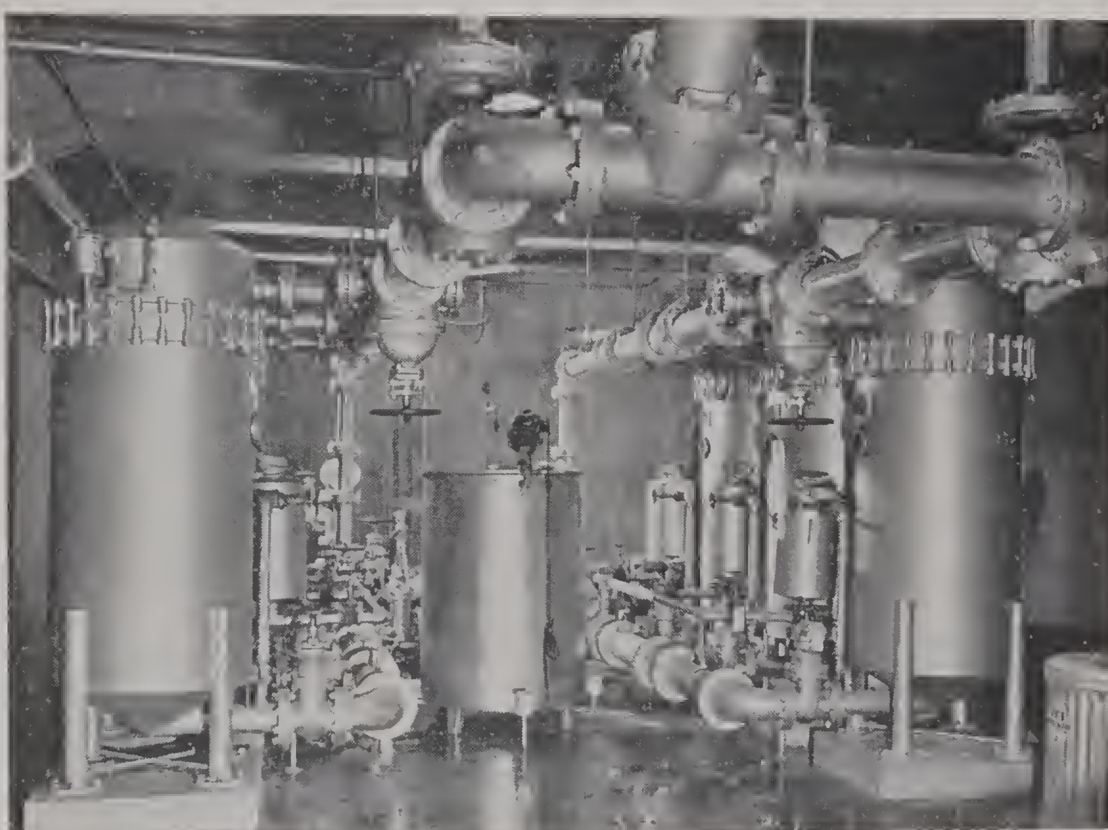

FIG. 87a. Diatomaceous earth filter installation. (Courtesy, Proportioneers, Inc.)

tus must be at hand to test the pH of the water. The desirable range has been found to be 7.2 to 7.6. A pH lower than 7.2, i.e., 7.1 or 7.0, would give better bactericidal activity but it would also result in more trouble to swimmers because of irritated eyes. Likewise, testing kits to determine the chlorine residual must be available at all pools and the operators responsible for the pool must know how to make readings.

Some pools were built before chlorinating equipment was available. Operation of these will present a public health hazard, but there are times when it is desirable to make-shift and permit operation of such pools. Calcium hypochlorite can be scattered over the pool by hand, the water agitated by means of paddles and then tested to determine the residual content. With practice the operator can determine how much of the high

test compound he must add to get the desired residual. Since this method of application will result in areas of excessive concentration until the water is agitated, swimmers should not be allowed in the water during the chlorinating process. Tests should be taken at least every 2 hours once swimming has been started so that the pool can be rechlorinated when the residual drops below the desired strength. This means that the pool must be emptied of swimmers. Quite obviously, this is an undesirable method and should be resorted to or permitted only under unusual conditions.

Bromine has found wide use in Illinois where in 1948 about 10 percent of public pools used this chemical. Water is bubbled through liquid bromine at a rate fast enough to give the concentration of bromine desired in the pool. Advantages in the use of bromine are given as:[1]

> "Operators using bromine are quite partial to it, mainly for reasons aside from its disinfecting power. They claim the equipment is safer and easier to operate and maintain than a gas chlorinator, the bromine residual is more stable and tenacious than chlorine residual, there is less likelihood of swimmers complaining of odors and irritation, and the bromine keeps the filter sand in cleaner condition."

Bromine in waters low in organic matter is equally effective with chlorine as a bactericide.

The orthotolidine test is effective for bromine in water, as it is for chlorine. The standard chlorine test kit can be used for determining bromine residual except that the residual of the latter will be twice that read on the chlorine test apparatus. A residual of 0.5 ppm. should be carried.

Bromine fumes are irritating to the eyes and lungs. Any of the liquid splashed on the skin will produce burns unless washed off promptly. Precautions in handling bromine should be about the same as those used in handling chlorine.

## Algae Control

In any type of pool, whether complete or partial treatment is given the water for sanitary control, algae growths will occur and must be prevented or removed. These green slimy growths appear on the sides and bottom of the pool producing a hazard to the bathers. The appearance of the water itself will also be less inviting. Tastes and odors will be imparted to the water which may be intensified by the chemicals used in the purification process. Prevention of algae growth rather than algae removal should be the aim of every pool operator and may be accomplished by treating the water continuously with small doses of copper sulphate. Application of copper sulphate in doses of from one to five pounds per million gallons has been found effective in most pools. The chemical is added by dragging a bag containing the required quantity for one application, 10 pounds for a

million gallons of water, around the pool until all the copper sulphate is dissolved. Treatment two or three times weekly, after the pool has closed for the day is suggested. This compound may also be fed to the water during the filtration process. Maintaining a *free* available chlorine residual in the pool water will prevent the growth of algae. Some of the quaternary ammonium compounds give promise of effective control.

## POOL CLEANLINESS

Although treatment of pool water is of paramount importance, the cleanliness of the pool itself must be given continuous attention if the pool is to be attractive and safe. New water should be added to pools each morning until the overflow of water into the gutters removes all floating material. Accumulations of dirt, suit lint, pieces of rubber shoes and caps and other debris will be found in the bottom of the pool. Algae which have been killed by copper sulphate will cling to the sides and bottom and must be removed by use of special vacuum cleaners or else be scraped to one of the pool outlets and flushed into the sewer. Pools should be cleaned in this manner before opening for the day and after the dirt has had time to settle from the previous day's operation.

Walkways, diving boards, slides and other appurtenances around the pool should be treated daily with a sterilizing solution similar to that suggested for locker room floors. Clarity of pool water should be such that distinct engraving may be seen on a dime lying on the bottom in deep water. Bacterial samples should be collected daily and tests for residual chlorine by the orthotolidine arsenite method made every 2 hours. pH determinations should be made at least daily and always after new water has been added.

## BACTERIAL STANDARDS

The efficiency of water treatment equipment and chemicals now available makes it possible to maintain swimming pool water that has bacteriological standards equal to those of drinking water. *B. coli* is taken as the test organism and many requirements call for counts no higher than would be acceptable for drinking water. (See discussion of drinking water, Chapter 6.) Two other counts are frequently made; one is the total bacterial count and the other a streptococci count. Standards vary from state to state and from community to community. A total bacterial count of 200 per ml. indicates unsatisfactory operation.

## RECORDS

Accurate records are very valuable in swimming pool operation as they provide a means for the health department to check the precautions being taken to protect the health of the bathers. In addition the pool operator

has this insurance against criticism of faulty or careless control. Occasional operating difficulties can be corrected by reference to previous treatment. Economy of the treatment as well as its effectiveness may also be determined. Many state health departments require weekly or monthly operating reports which can be obtained only from good daily records.

All chemicals added, the amount of water treated, number of bathers using the pool, the various chemical tests and results of bacteriological tests should be recorded on a daily operating sheet. A form shown in Figure

REPORT ON ______________ (Name of pool) SWIMMING POOL AT ______________ (City) FOR MONTH OF ______________ 19____

| DAY | PERSONS USING | RECIRCULATION HRS. | RECIRCULATION TOTAL GALLONS | NEW WATER ADDED Gallons | FILTERS WASHED | VACUUM Hrs. used | OVER-FLOWED TO WASTE Minutes | ALUM Lbs. | SODA ASH Lbs. | (OTHER) | COPPER SULFATE Lbs. | pH | TUR-BIDITY | TEMPERATURE 3 P.M. WATER | TEMPERATURE 3 P.M. AIR | CHLORINATION Chlorinator Operated Hrs. | CHLORINATION Chlorine Tank Lbs. Oz | RESIDUAL CL IN POOL PARTS PER MILLION Inlet A.M. | Inlet P.M. | Outlet A.M. | Outlet P.M. | REMARKS. Pool capacity in gals ____ A Bacterial samples to State B Chlorinator trouble |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 1 | | | | | | | | | | | | | | | | | | | | | | |
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| 30 | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | |

REMARKS (Indicate OVER if continued on reverse side) ______________

REPORT BY ______________ TITLE ______________

FIG. 87b. Swimming pool report form. (Courtesy, Clarence W. Klassen, Illinois Department of Public Health.)

87b has been used in one of the states for many years. A score card system for rating the swimming pools should cover engineering details of pool structure, ventilation, light, dressing room construction, showers, toilets, characteristics of water, bather control, and records. A comparison of these scores over a given period of time gives a true index of the efficiency or inefficiency of pool management.

## WADING POOLS

Wading pools are frequently provided adjacent to swimming pools for the entertainment of young children. Similar facilities are provided in parks and playgrounds. Control of the habits of the youngsters is not so easy as

is the case for adults using swimming pools. As a result, much more pollution enters wading pools than is the case in swimming pools, considering the number of people using each. In addition, wading pools are usually relatively small.

Many of the children will get down in the water of the wading pools and either attempt to swim or crawl around in the water. Others may scoop the water up in their hands and drink it. Adequate measures must be taken to protect the children against infection through the water.

The wading pools should be drained and refilled at least twice a day. A constant flow of fresh water should be added to the pools whenever they are in use. Since the degree of pollution of the water is likely to be high it is better to waste water from the pool than to attempt to treat the water in conjunction with swimming pools. A residual of 0.5 ppm. of free available chlorine should be maintained in the fresh water entering the pools. Toilets adjacent to the wading area are desirable.

## NATURAL BATHING AREAS

The sanitation of natural bathing areas is more difficult and variable than that of artificial pools. With the latter, pollution comes either from the water admitted to the pool or else from the bathers. The quantity of each can be compensated for by methods of treatment. The pollution in natural waters is something that cannot be measured. Besides, the volumes are usually much larger than any found in artificial pools. The effect of sunlight and tides has a contributory influence on the quality of the water at any one time.

The physical facilities provided for bathers at artificial pools should be made available at natural bathing beaches. These include properly constructed dressing and bathing rooms, toilets, and drinking water. Life guard precautions must be more extensive. However, the general operation of the area is the same as that for artificial pools.

The bacteriological quality of natural bathing waters can be controlled to a much less degree than can waters in artificial pools. Furthermore, there has been no proof of illness transmitted through natural bathing waters. Although bacterial counts are accepted as having some significance there is no agreement on specific limits of pollution. There is general agreement on the fact that obvious signs of pollution with human excrement is more important than bacterial counts. All natural bathing waters should be inspected to determine whether or not there is any possibility of wastes from septic tanks, cesspools, privies, or primary sewage treatment plants entering the bathing waters through the action of currents, tides, wind, or other natural forces. If such pollution is possible, the bathing area

should be condemned for bathing as a precautionary measure. Location of foci of human waste pollution is particularly important in fresh water bathing areas where the quantity of water may be much less than that found in salt water beaches.

Studies have been made in an effort to determine reasonable bacterial standards. One state has made extensive surveys of the physical charac-

FIG. 87c. Exterior swimming pool, Audubon Park, New Orleans, La. (Courtesy, Roberts Filter Manufacturing Co.)

teristics of salt water beaches and correlated those with *B. coli* counts. On the basis of this study the following bacterial standards were set:

| *Average Coliform Index* | *Per 100 ml.* |
|---|---|
| Class A | 0 to 50 |
| Class B | 50 to 500 |
| Class C | 500 to 1000 |
| Class D | Over 1000 |

When coliform organism densities exceed 1000 per 100 ml. the beach is considered unsafe.

Class A was considered good, Class D poor and the other two inter-

mediate classes ranged from fair to doubtful. The result of the physical surveys corroborated the bacteriological findings.

New York City has adopted standards for its beaches, including a bacterial standard. They are:

Class A: Approved Beach Waters
  Group 1. Safe Waters
    (a) Epidemiological experience satisfactory, and
    (b) Sanitary survey satisfactory, and
    (c) Coliform average not in excess of 1,000 per 100 ml.
  Group 2. Approved, but subject to reclassification in light of continuing observation.
    (a) Epidemiological experience satisfactory.
    (b) Sanitary survey satisfactory but beach waters exposed to increasing pollution, or
    (c) Coliform average above 1,000 but not in excess of 2,400.
Class B: Polluted Beach Waters Not Recommended for Bathing
  (a) Epidemiological experience satisfactory
  (b) Sanitary survey discloses sewage material on beach or in water immediately adjacent to beach, and
  (c) Coliform average above 2,400, with 50 per cent of samples in average above 2,400
Class C: Unsafe Beach Waters
  (a) Epidemiological experience discloses evidence of infection incident to beach bathing
  (b) and (c) Not necessarily relevant in light of (a) above.

## SUMMARY

Even though there is little conclusive evidence to show the transmission of disease through waters in swimming areas the possibility of such in unregulated pools and beaches is something that must be recognized. There can be no question of the positive value to health of good, well-regulated facilities. Information of a definitive nature is lacking to show what standards of sanitation must be attained to protect health. Some principles have been suggested. It behooves all persons active in public health duties to investigate further any factors that seem to indicate relationships between disease and conditions in swimming pools. Equally important is the interest of these people in maintaining the conditions of swimming areas in good shape so that the maximum positive value can be obtained from them.

### LITERATURE CITED

[1] Klassen, Clarence W., Circ. No. 125, p. 30, Illinois State Dept. Health, 1948.
[2] Swimming Pools and other Public Bathing Places, Recommended Practice for Design, Equipment and Operation, American Public Health Association, New York, 1949.

Chapter XII

# ENVIRONMENTAL SANITATION AND PUBLIC HEALTH

The term "environmental sanitation" in its broadest sense includes all of those factors of the environment that may have some influence on the health—both from a positive and a negative viewpoint—of man. In this chapter the term is used to refer only to those more direct influences of the environment that play a part in the health of everyone. Food, water, and sewage have been discussed already. Insects, rodents, and general ventilation will be treated later.

The sanitary control of the environment is usually necessitated by the crowding of people into comparatively small areas. The more favorable conditions under which people live the healthier they will be. Atmospheric pollution, poor housing, excessive noise, and industrial hazards are important factors in every day living. These are conditions applicable to urban areas particularly although those of poor housing and certain industrial hazards are important in rural areas.

## ATMOSPHERIC POLLUTION

Air contamination is associated with population density and with industrial activity with its contributions of gases, fumes, mists, dusts, and odors to the atmosphere. Some of these contaminants may be classified only as nuisances, while others, if present in sufficient quantity, may affect health. Certain dusts and gases may be present naturally in outdoor air in amounts too insignificant to be of public health importance. These same materials may be disseminated in sufficient concentration in the atmosphere at industrial plants to affect the health of the employees. Contaminants of the atmosphere are of a diversified character. Advancement of our knowledge of the relation of these foreign materials to comfort and well being has resulted in an increasing demand for clean air.[22]

It must be remembered that occasionally demands for air cleanliness are unreasonable.[12] The air of an industrial city cannot be as clean as that of the open country, and this is part of the cost civilization must pay for the benefit of industry. However, industry has an obligation to do all possible to minimize air pollution. Although unhealthful air conditions are the usual basis of complaint the actual proof that health is affected has been obtained only in a few instances. The most common contaminants, smoke, fly ash, dust, and odors offend the senses and are a nuisance but they are not usually definite health hazards.

Within the past 20 years there have been two known disasters caused by fumes and smoke laden fog. A heavy fume laden fog settled over the Meuse River valley near Liège, Belgium for 3 days during December 1930, causing 63 deaths from pulmonary complications. Cattle, birds, and other animals were killed.[10] More recently in October 1948 at Donora, Pa., a town of 13,000 population, heavy fog impregnated with smoke and fumes from steel mills and other industrial plants persisted during a period of 4 days causing 20 deaths from cardiac-respiratory tract causes. Analysis of the atmosphere showed the presence of fluoride, chloride, oxides of nitrogen, hydrogen sulfide, cadmium oxide and sulfur dioxide as the possible respiratory trace irritants.[31, 45] Industrial atmospheric impurities during fogs in the Los Angeles, Calif., area produce serious irritations of the eyes and nasal passages. These conditions occur intermittently and are directly related to temperature inversions.[46] (Temperature inversions are observed primarily in valleys or bowl shaped topography. Through various meteorological conditions a blanket of warm air overlies the cool air in the valley. Thus a condition contrary to that normally found occurs with lighter high layers of air preventing the usual convectional air currents that would carry away much of the contamination.)

## Smoke and Dust

Smoke emission is spectacular and receives the most criticism for causing air pollution but actually fly ash and dust are of equal importance. A recent committee report (1948) of the American Public Health Association states:

> "Smoke alone, for example, in excessive quantities is disagreeable, discomforting, and of economic significance, but the evidence so far collected has not been able to establish a definite relationship between smoke and health.
>
> "The discharge into the atmosphere of dusts from industries such as smelters, cement plants, rock crushers, sand blast plants, and roofing plants, and of some of the organic dusts may, however, have health implications."[34]

Smoke is a product resulting from the incomplete combustion of any fuel and is composed chiefly of finely divided particles of unburned carbon. Other constituents such as tarry compounds, sulphur dioxide and sulphur trioxide, sulphurous or sulphuric acids, hydrogen sulphide, carbon monoxide and carbon dioxide and a fine ash containing silica and iron compounds are found in varying amounts. Some types of coal, such as soft coal or gas coal, produce much more smoke than the so-called low volatile or semi-bituminous coal. Anthracite or hard coal is known as a smokeless coal. The various grades of soft coal and fuel oil, when improperly burned, are chiefly responsible for the nuisance.

The constituents of smoke which are responsible for damaging effects are

the tarry and sulphurous compounds. In the presence of moisture the sulphur dioxide and sulphur trioxide are converted into sulphurous and sulphuric acid. These acids, together with the tarry compounds, which act as a coating, accumulate on the surfaces of buildings, household materials and vegetation, corroding exposed metal surfaces, and retarding the growth of or destroying trees, shrubs and other vegetation.

Smoke and dust particles reduce sunlight, produce a haze, and increase the density of fogs. The economic loss from smoke and dust has frequently been evaluated for different cities and varies from $10 to $30 per capita per year.[15] The classic investigation in 14 of the largest cities in the United States, reported in 1936, established fundamental data upon which to base smoke and dust abatement programs.[14]

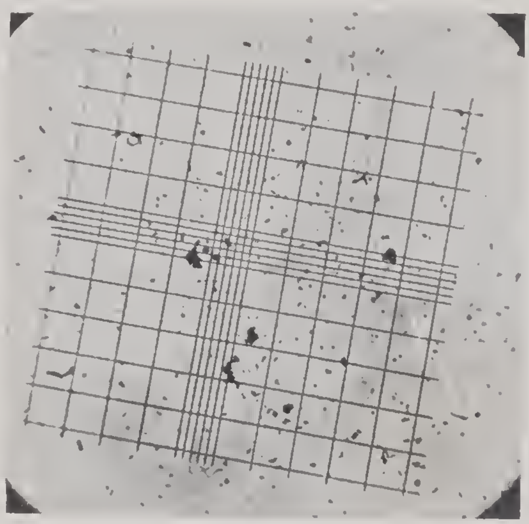

FIG. 88. A micro photograph of atmospheric dust

This study found that such factors as the season of the year, time of the day, and wind velocity were of significance in causing variations in the amount of pollution. Contrary to the belief that "rain clears the air" the records of the automatic air filters used as part of the study, failed to show any definite decrease in atmospheric pollution. The average amount of suspended matter in the air during the winter months was 5.1 milligrams per 10 cubic meters of air; of which 65 percent consisted of carbonaceous matter, 35 percent ash, 12 percent silica and 2 percent iron oxide. The sulphur content of the atmosphere averaged 0.73 milligrams in 10 cubic meters of air during the winter months and showed a close correlation with the amount of carbonaceous matter present. The median size of the dust particles suspended in the air was 0.58 micron. An average of 815 dust particles per cubic centimeter of air was found during the winter months. Atmospheric pollution was found to be greatest in the winter, reaching a maximum in December or January. The greatest density occurred about 7:30 in the morning, with a lull during the noon hour. The minimum was

about 3:30 in the morning with a secondary maximum at 8 P.M. The velocity of the wind was found to have a marked bearing on the degree of pollution, particularly during the morning "starting up" or the 7:30 period. There have been many subsequent studies of dust and soot fall in various cities that have in general confirmed the basic principles cited above.[9, 23, 25] The technique employed depicts variations in atmospheric conditions rather than accurate evaluation of fly ash and soot deposited from specific locations. It is now realized that the amount of material deposited in a given collector is affected by wind velocity, position in relation to higher or lower buildings, rainfall, and size of collector openings. Results may therefore vary over wide ranges. A recent test in Pittsburgh showed that atmospheric inversion is the most important factor in the occurrence of high dust counts and that measurement of dust deposition at a given location does not reflect general combustion conditions.[8]

The Ringleman chart is commonly used as a measure of smoke density.[17] Black smoke is defined in many ordinances as the concentration equivalent to No. 2 grade on the chart. Usually the law limits the emission of such smoke to a period not exceeding 2 minutes in every 15 minutes of firing. Violations are subject to fine. Air pollution surveys should include the number of suspended particles, with their weight and composition, in a specified volume of air; density of condensation nuclei; measurement of daylight transmission; and the concentration of ultraviolet radiation. Various types of apparatus have been developed for the sampling of dust in air, such as electric precipitators, filters, impinging plates, and atomizers.[5, 11, 21]

Smoke control ordinances are usually drawn to regulate industrial firing, but there is also a tendency to include dwellings. Railroad engines are often required to observe the Ringleman standard. Mechanical stokers are being increasingly utilized to feed coal into the fire box continuously and erratic combustion temperatures with resultant release of unburned carbon particles as smoke, so frequently seen with hand firing, is eliminated. The widespread substitution of oil-burning for coal burning locomotives has had a marked beneficial effect in reducing smoke pollution. Small industrial plants, apartment houses, hospitals and similar institutions retaining hand fired heating equipment are the greatest offenders. Careful supervision and training of firemen can decrease the frequency and duration of dense smoke periods.

Fly ash must be removed by mechanical precipitation, filters, or by electrostatic precipitation. The equipment is expensive and for this reason difficult to force small plant owners to install it.

Control practice is based upon an inspection service with an educational program for plant owners and firemen. Educational methods should be of a

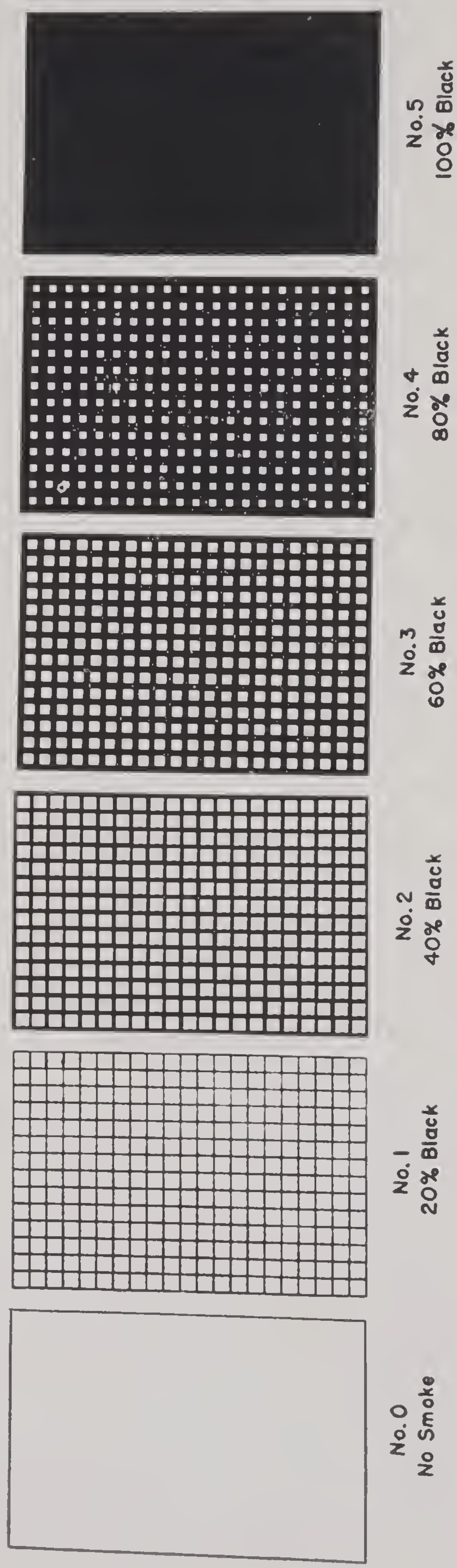


FIG. 89. The Ringleman chart. Bureau Mines Inf. Circ. No. 7090

general and of a specific nature. Plant operators, management, apartment house superintendents, and individual house owners must be made air pollution conscious and taught to desire better conditions. Specific methods consist of discussions with these groups to show how operations can be changed, equipment altered, or types of fuel varied. Meteorological conditions should be studied and efforts made to locate industries likely to produce objectionable smoke, odors, or fumes on the side of the city away from the prevailing winds. Field crews must be available for studies to locate centers of pollution and to mark the progress of improvement or deterioration. Well trained and competent personnel are required for the work. The use of police authority is reserved for the flagrantly uncooperative violator.[6, 8, 24, 27, 34]

Smoke control enforcement has not been established exclusively as a direct function of health agencies. A publication of the Bureau of Mines[50] distributes the responsibility for enforcement as follows:

| | |
|---|---|
| Public Works Department | 24 percent |
| Building Department | 23 " |
| Public Safety Department | 20 " |
| Health Department | 18 " |
| Fire Department | 6 " |
| Miscellaneous | 9 " |

## Odors and Fumes

Fumes may be considered as vapor or solid particles having diameters between 0.1 and 1.0 micron dispersed in air.[1] They are the basis of heavy fogs condensed over industrial areas and frequently contain considerable sulfur bearing oil fumes. Concentrations of free sulfur between 5 and 10 ppm. within the densities encountered from oil burning equipment produce eye smarting.[16] Other mucous membrane irritants emitted from industrial plants include: "sulfur dioxide, chlorine, phosgene, and eye irritants such as acrolein, butadiene, and hydrogen sulfide."[34]

Malodorous substances frequently produce complaint at intensities varying from 0.0001 to 0.1 ppm.[28] The safe concentration of sulfur dioxide at ground level has been determined and established at 0.5 to 0.75 ppm.[13] Apparatus has been developed which measures and records the concentration of several gases in air making possible accurate study of their distribution in a given area.[30] Unusual odors are likely to cause complaints because the public is not accustomed to them.[32]

The belief that foul odors cause illness and also are a factor in the spread of communicable disease is tenaciously adhered to by many persons. Some atmospheres with unpleasant odors such as those of hydrogen sulphide and sulphur dioxide, may be harmful if the gases are present in sufficient concentration. Generally they originate from industrial processes

such as glue factories, fertilizer production, slaughter houses, and oil refineries. They can be prevented or controlled. Unpleasant smells caused by decomposing garbage, tanneries, rendering plants and sewage may affect the appetite and cause nausea, vomiting, headache and dizziness. These effects are only temporary, disappearing with the removal of the cause or with the senses becoming accustomed to them.

The state of California has enacted a new law establishing "air pollution control districts" coincident with county boundaries,[24] and Cleveland, Ohio, has combined smoke abatement, industrial nuisance and industrial hygiene into an air pollution control unit of the health department. Regardless of organizational arrangement air pollution abatement is a direct responsibility of cooperative action among these agencies.

Fume and odor elimination is practical only at the source.[26] They are problems for industry with supervision by control agencies. Removal from industrial waste gases may be accomplished by passage through scrubbing towers or by burning in special furnaces.

## Pollen Control

The full public health significance of allergic responses to pollens has not been determined, but the elimination of pollens has been assuming greater importance in recent years. One estimate puts the number of persons east of the Rocky Mountains who suffer from ragweed hay fever at 3,000,000. The United States Public Health Service has estimated that the ragweed growth east of the Rockies is sufficient to cause symptoms in 2 to 3 percent of the population of that area.

Ragweed is the principal offender in hay fever caused by pollens. Control measures are directed toward the elimination of the ragweed plant. The plant grows in freshly disturbed ground and extensive areas are found only where there is considerable construction of new buildings. Unfortunately ragweed produces prodigious quantities of pollen and their seeds have been found viable 40 years after production. Pollen grains may be blown many miles so that the reasonable goal in any area seems to be a reduction in pollen incidence to the point where allergic people are not affected by the small amount remaining.

Control programs, until a few years ago, consisted of cutting growths of the weed. In many communities this was a cooperative effort; in others, local ordinances required owners to keep their property free of the weed. Enforcement was difficult. The availability in 1944 of the new herbicide, 2,4-D (2,4-dichlorophenoxyacetic acid) changed the control program completely. This chemical, when sprayed on the leaves of the plants, kills most broad-leaved plants, including ragweed. It is relatively inexpensive, highly effective, and easy to use.

Responsibility for control operations is being placed in the health department in many communities. The operations are usually undertaken by sanitation or street cleaning personnel with the health department directing and coordinating the work and the police department making the inspections. Since the usual mosquito control equipment can be used for spraying weeds, county mosquito control units are conducting the field control programs in many rural or urban areas. In come communities the program has been financed from the tax levy; in others, by a charge to property owners.[33] Pincus reports[51] that in New York City one application of 2,4-D was successful in killing ragweed at a cost of $11 per acre for chemicals, labor, and equipment hire.

## Carbon Monoxide

Carbon monoxide when present in inhaled air combines with the hemoglobin or red pigment of the blood. The hemoglobin of the blood holds oxygen in loose combination and carries it to the body tissues. The affinity of hemoglobin for carbon monoxide is about 250 times its affinity for oxygen. Because of this relationship carbon monoxide when inhaled reacts with the hemoglobin to form carboxyhemoglobin. The oxygen so combined is not available for the usual task of carrying oxygen to different parts of the body. The serious deprivation of hemoglobin results in death from asphyxiation. Severe asphyxiation frequently does not end in death but may leave permanent injury to the brain tissue.

Carbon monoxide poisoning depends on the concentration of the gas in the air and the length of time of exposure. Since it is a colorless, odorless, and tasteless gas, its presence is not detectable until symptoms of poisoning are noted. A concentration of 0.04 percent in the air will cause mild symptoms in about two hours, while 0.15 percent causes severe symptoms within an hour. It is believed that for prolonged exposures the concentration should not exceed 0.01 percent (100 ppm.). High temperatures, high humidities, and muscular exercise increase the absorption rate of carbon monoxide in the blood.[7]

Whenever organic materials such as coal and oil are burned, carbon monoxide is the first product in the combustion process. If an adequate supply of air is available, and if the temperature is sufficiently high, this gas is burned to carbon dioxide, a harmless gas. If the fuel is not completely burned because of poorly constructed heating plants or defective vents and obstructed passageways in chimneys, some carbon monoxide may escape into the building.

The increasing use of illuminating gas as a fuel and the widespread popularity of automobiles, motor boats and airplanes have multiplied the possibilities of exposure to carbon monoxide. The use of internal combus-

tion engines in these conveyances results in significant concentrations of carbon monoxide in the exhaust fumes. The content in automobile gas is high, varying from 1 to 7 percent and at times it may be higher. On the other hand, the exhaust from diesel engines is quite safe under normal operating efficiency.

Numerous deaths have occurred as a result of permitting the air in closed garages to become dangerously rich in carbon monoxide because of the continued operation of automobile engines. The atmosphere in a single car garage will become deadly within about five minutes if the motor is run and no ventilation is provided. Carbon monoxide hazards may also exist from leaking exhaust pipes while driving automobiles if windows are kept closed. Leaky gaskets also may permit exhaust gas to penetrate through loose footboards and cause asphyxiation. Smaller concentrations, insufficient to cause asphyxiation but sufficient to affect the mental alertness of the driver, have been held as one of the causative factors in automobile highway accidents.

The discharge of carbon monoxide by automotive traffic has been found to vary on city streets from 6 ppm. to 32 ppm. Exposure of patrolmen at points of particularly high concentrations such as 100 ppm. during an 8 hour day produced noticeable, but not serious symptoms of carbon monoxide poisoning. It is therefore concluded that the atmosphere in normally congested city areas should not be considered hazardous from carbon monoxide. The obnoxious odors from automobile exhausts is due to the concentration of aldehydes exceeding 10 ppm. and also to possible decomposition of sulfur compounds. Poorly designed, defective and improperly adjusted gas appliances have been responsible for numerous asphyxiations and deaths from carbon monoxide gas. Cognizance of the hazards entailed in faulty equipment aroused the interest of manufacturers, service companies, and governmental agencies in the protection of the public from these dangers.

Health Department investigations of asphyxiations associated with gas-burning appliances revealed a considerable percentage attributable to improper installation or adjustment; to improper design; to deterioration or clogging of vital parts; and to carelessness or ignorance in their operation.

Gas appliances should be connected with rigid piping. The flexible type of tubing deteriorates in time, the ends become enlarged from usage and as a result may accidentally be disconnected, permitting unburned gas to escape. Flexible spiral metal tubing or plain rubber tubing should never be used since it deteriorates and cracks after relatively short usage. Gas appliances should not be tampered with nor should attachments of unknown merit be added to them. Operating standard appliances in non-

standard or novel ways has resulted in the production of carbon monoxide by devices which perform safely under normal conditions.

Health department control over gas appliances and fixtures began in 1925 and has proved its effectiveness by eliminating those of hazardous design or installation.

## HOUSING

Generally slum areas in large cities are located near business centers where high class residences once existed. As various business enterprises crept in, the original residents moved out to more desirable locations. Large and, at one time, substantial single-family houses were transformed into multiple-family houses or rooming houses to accommodate the new tenants. The houses were not designed for this type of occupancy and lack of proper plumbing or failure in maintenance resulted in slow but sure deterioration. In such areas the original population tends to decrease, the residents with better economic means moving whenever possible to outlying sections where they can establish themselves in a more favorable environment. A typical survey of a slum area disclosed 9.7 percent of the houses in good condition; 24.8 percent of indifferent status; and 65.5 percent bad.[35]

### Significance of Poor Housing

One of the characteristics of slum areas is overcrowding. Because of economic conditions families are compelled to double-up or large families to live in quarters entirely too small. As a result of this congestion children by necessity play and congregate in hallways of tenements and in the streets. This "herding together" and intimate contact of numerous persons offers a favorable condition for the transmission of communicable disease, first in the slum district itself and subsequently to other parts of the city population.

Typical of poor housing is the inadequacy of light, ventilation, and privacy. Frequently living quarters for an entire family comprise one or two small rooms. In many instances inside rooms are without direct outside light or ventilation. These rooms are often used as bedrooms, probably by an entire family. Continuation of such housing conditions, where children lack an adequacy of sunlight and fresh air, and where there exist no recreational areas for healthy outdoor exercise, prevents the healthy development of the tenants.

The various states of dilapidation of many dwellings in slum districts favor the occurrence of accidents and often prevent proper protection from inclement weather. Defective stairs and floors, unrepaired sheds and porches suggest the probable clue to the cause of many accidents. Broken windows, defective walls and roofs make it difficult to keep out rain, snow and wind.

Heating devices, often in a deteriorated condition, offer a possible carbon monoxide hazard. Frequently the tenants of such properties pay exorbitant rent and owners are reluctant or financially unable to make repairs.

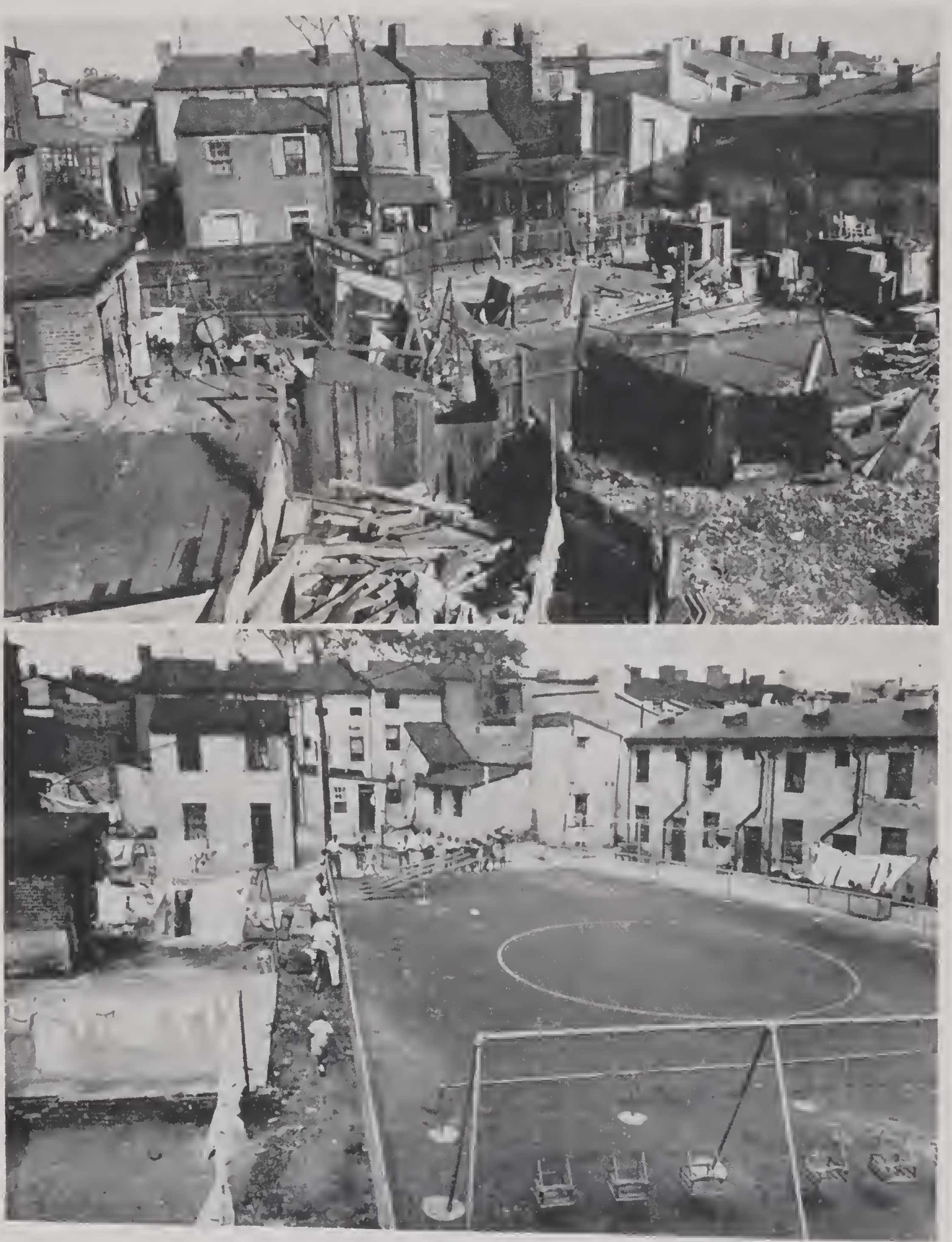

FIG. 90 (upper). Typical poor housing conditions
FIG. 91. Same area as in figure 90 after rehabilitation by "area redevelopment"

Living under poor housing conditions leads to a development of carelessness in living habits. Cellars, yards, and alleys become cluttered with

rubbish frequently containing garbage, offering not only a fire hazard but an attraction for flies, vermin, and rats. Yard toilets often become choked or defective, tenants continue to use them, and sewage flows into yard and alley. Sanitation is given little consideration when the entire environment is unfavorable.

Anyone who has had any contact with poor housing and its attendant conditions will recognize the psychological difficulties that are inherent in the lack of privacy, the unusual noise, and general confusion typical of poor housing areas.

## Basic Requirements of Good Housing

The basic requirements of good housing may vary somewhat from one part of the country to another. Some satisfactory method of heating the living portions of the home would be much more important in New England or Minnesota than in southern Georgia. Until recently, screening of windows in certain portions of the southeastern United States might have been necessary as a direct preventive against the spread of malaria. Such would hardly be the case in central Maine but screening might be necessary there to protect against nuisance mosquitoes.

The Committee on the Hygiene of Housing of the American Public Health Association has given extended study to basic needs in housing. It suggests the following as the minimum requirements of any housing:[38]

**A. Fundamental Physiological Needs**

Maintenance of a thermal environment which will avoid undue heat loss from the human body.

Maintenance of a thermal environment which will permit adequate heat loss from the human body.

Provision of an atmosphere of reasonable chemical purity.

Provision of adequate daylight illumination and avoidance of undue daylight glare.

Provision for admission of direct sunlight.

Provision of adequate artificial illumination and avoidance of glare.

Protection against excessive noise.

Provision of adequate space for exercise and for the play of children.

**B. Fundamental Psychological Needs**

Provision of adequate privacy for the individual.

Provision of opportunities for normal family life.

Provision of opportunities for normal community life.

Provision of facilities which make possible the performance of the tasks of the household without undue physical and mental fatigue.

Provision of facilities for maintenance of cleanliness of the dwelling and of the person.

Provision of possibilities for esthetic satisfaction in the home and its surroundings.

Concordance with prevailing social standards of the local community.

**C. Protection Against Contagion**

Provision of a water supply of safe sanitary quality, available to the dwelling.

Protection of the water supply system against pollution within the dwelling.

Provision of toilet facilities of such a character as to minimize the danger of transmitting disease.

Protection against sewage contamination of the interior surfaces of the dwelling.

Avoidance of insanitary conditions in the vicinity of the dwelling.

Exclusion from the dwelling of vermin which may play a part in the transmission of disease.

Provision of facilities for keeping milk and food undecomposed.

Provision of sufficient space in sleeping-rooms to minimize the danger of contact infection.

**D. Protection Against Accidents**

Erection of the dwelling with such materials and methods of construction as to minimize danger of accidents due to collapse of any part of the structure.

Control of conditions likely to cause fires or to promote their spread.

Provision of adequate facilities for escape in case of fire.

Protection against danger of electrical shocks and burns.

Protection against gas poisonings.

Protection against falls and other mechanical injuries in the home.

Protection of the neighborhood against the hazards of automobile traffic.

### Slum Clearance

Particular aid is necessary in providing good housing for the low-middle and low income groups. Private industry takes care of those better able to pay. This need has been summarized by Marquette[8] as follows:

> " 'Housing' connotes more than the mere condition, design, arrangement, and construction of buildings. It means the conditions under which people carry on their daily life, in their homes and in their neighborhoods. It means the general environment as well as the buildings. Concrete examples of what housing means today are found in the public housing projects, nonexistent a decade ago. These projects are undertaken to the kind of environment that favors physical and mental health. They insure essentials in wise site planning such as low percentage of land occupancy by buildings and the orientation of structures so that the maximum amount of sunshine will be available. Provision is made for sufficient window area and such arrangement of windows as will give maximum ventila-

tion; for insulation against heat and cold; arrangement of rooms for maximum privacy; modern toilet and bathing facilities for every dwelling unit; hot as well as cold running water; efficient heating; laundry facilities; fire resistant construction and safe egress. Thought is given not only to minimizing conditions that are conducive to falls and accidents, but to provide the kind of management that will insure the maintenance of the buildings in a good state of repair. With elimination of overcrowding it is possible to direct the attention of tenants to the habits of cleanliness and orderly housekeeping. Projects are planned to include ample room for adult recreation and convenient play space for children."

Viewed in this broad light few health leaders question the statement that good housing does promote good health. At the same time, recognized housing leaders do not discount the fact that health is vitally affected by other factors, such as adequate income, proper diet, good medical service, cleanliness, the knowledge and practice of the rules of hygiene, and conditions of employment.

Slum clearance and housing aid programs rest upon the rebuilding of the older portions of our cities.[38] The new structures replace dilapidated properties but unless subsidy in various forms is given the projects to provide maintenance funds, it is fair to assume the remedial structures will degenerate into slums a few years hence. The educational and social level of the majority of people occupying this type of housing frequently is not conducive to satisfactory maintenance of property.

Generally speaking housing units provide accommodations for slightly more people than lived in the area before slum clearance. However, the new tenants are selected and in many instances the persons displaced do not find shelter in the new project but seek slum quarters elsewhere. In the overall picture the number of persons living in slum conditions has been reduced. Poor people will of necessity seek low cost housing and regardless of sub-standard conditions live in slums because they cannot help themselves.

**Low Cost Housing.** The Metropolitan Life Insurance Company pioneered in the low cost housing field in 1920 by building a unit for 2,250 families in Queens, New York. Other units have been constructed and in 1934 the Reconstruction Finance Corporation provided funds to the Metropolitan for limited dividend housing. These initial projects have in recent years been extended by life insurance companies to many cities reaching an investment of $275,000,000.00 and housing 150,000 families in 10 states. Stuyvesant Town and Peter Cooper Village in New York housing 11,250 families are the latest erected initially for moderate income groups ranging from $1,500 to $4,000 per year. Figure 92. Low cost apartment houses vary from three story units to large twelve story buildings of the Knickerbocker type. Units rent from $9 to $19 per room per month depend-

ing upon prorated construction and maintenance costs. These developments have been made economically possible by tax exemptions with rents paying a moderate investment return and operating costs.

**Government Housing.** The United States Housing Act of 1937 put the Federal Government into the slum clearance and low rent housing field. Under this Act local housing authorities were created to engage in slum clearance and low rent housing construction. Local agencies initiate

FIG. 92. Stuyvesant Town and Peter Cooper Village, New York City. (Courtesy, The Metropolitan Life Insurance Co. Photograph by Thomas Airviews.)

the project, construct and operate the housing unit. They have been granted the right of eminent domain to aid in the acquisition of dilapidated buildings. Ninety percent of the cost of the project is financed from federal funds with the balance from private capital at low interest rates or from municipal budgets. Federal money is loaned for a period of 60 years from an $800,000,000 fund originally established for this purpose. In addition yearly federal contributions may be secured to "assist in achieving and maintaining the low rent character of the housing project."[29] Local authorities must contribute a sum which may be in cash or by tax exemption equal to 20 percent of the total operational costs.

Local housing authorities must remove "slum dwellings equal in number

. . . for every new family unit constructed."[29] These new units rent from $9 to $15 per room per month depending upon the *income* of the renter, and not related to the physical characteristics of the apartment furnished. This method is in sharp contrast to private financing based upon prorated costs.

**Area Redevelopment.** Several cities have created agencies as a part of municipal government to plan for the redevelopment of slum areas. These departments work closely with the zoning and planning bureaus in determining the location of present slum and blighted areas, policies of future, long-range development, and providing for cleared areas. They have the right of eminent domain to facilitate removal of buildings but are not required to restore housing on the sites cleared. Their object is to interest private capital in the development of cleared sections and commercial buildings or housing may be constructed in accordance with the general city plan and zoning ordinance. Funds of the magnitude of several million dollars from bond issue or other municipal sources are used to acquire land and demolish existing buildings after which the area may be sold or leased at market value to private enterprise for development. Tax exemption for a limited period is usually granted to the leasee or purchaser to facilitate a reasonable return on the investment. By the establishment of a revolving fund consisting of rents and resale moneys it is expected that the original funds allocated will support the program for many years.

## Public Health Program

The health department should be interested in providing housing that will permit the best public health. This should include interest not only in the physical but also in the mental health of the population group. A clear demonstration of the direct and specific relationships between poor housing and health must be established. This responsibility should be accepted by every health department as a continuing program of research to be conducted in any situations that may have some relationship to the subject. No other department of municipal government can perform this necessary function so well as the health department.

The health department must also take its place with other departments of government in planning and executing rebuilding, rehabilitation, and maintenance programs in housing. Provisions must be made for public health services in any new or rebuilt areas. Adoption of an overall plan for the delineation of areas of the city needing attention should be one of the first steps taken. The health department can give valuable aid here because the best, and perhaps the only, objective method for measuring the quality of housing has been developed as a public health tool. The Committee on the Hygiene of Housing of the American Public Health

Association[40] has developed with the aid of several experts in the field of housing, measurement methods and statistics, an appraisal method for measuring the quality of housing. The present recommended methods have been tested in the field and changed as experience has indicated. The methods have been used officially in several cities including Brookline, Mass., Los Angeles, Milwaukee, New Haven, Philadelphia, Portland, Me., St. Louis, and Washington, D. C.

The appraisal methods can be used to determine the condition of an individual building or the conditions of all buildings in an area. It measures not only the physical conditions of the structures but also the features of the neighborhood that have public health significance. Ratings are based upon penalty scores as determined by the inspection of buildings or areas. Certain conditions are classified as basic deficiencies which not only increase the penalty score but also indicate complete inadequacy in that particular part of the structure. The basic deficiencies the Committee has established are:[4]

1. Contaminated water supply.
2. Water supply outside unit or structure.
3. Toilet shared or outside the structure.
4. Bath shared or outside the structure.
5. Crowding of more than 1.5 persons per habitable room.
6. Crowding of sleeping rooms (persons = 2 × number of sleeping rooms + 2).
7. Less than 40 sq. ft. of sleeping area per person.
8. Lack of dual egress.
9. Installed heating lacking in three-quarters of rooms.
10. Lack of installed electricity.
11. Rooms lacking window.
12. Serious deterioration.

Supervision of sanitation in slum areas is a responsibility of the local health department. Close cooperation with the building and fire departments in conducting surveys is necessary to avoid duplication of inspection and to obtain a definition of responsibility. Determination of existing defects listed above should be the chief responsibility of the health department and inspection to locate them belongs in the sanitation section of that department. Enforcement and inspection procedures vary in different communities in accordance with local laws and ordinances.[37] Experience has demonstrated that enforcement of a housing code is best accomplished on an area basis rather than by the correction of single buildings, acting upon specific complaints.[35] All owners are thus treated alike and everyone is required to comply with the law. The police power of the health department can be invoked when public health is in danger.

The enforcement agency acting within the agreed overall plan should choose a slum area, inspect it, rate existing violations, and compile notices for correction. If conditions are uncorrected after the date established for the cessation for violation it may be necessary to exercise police power and force compliance through court action. This procedure of improving housing through law enforcement originated in Baltimore, Md. in 1947.[36] A magistrate's court has been established to adjudicate cases involving violations of housing ordinances.

Enforcement of a housing sanitary code does not preclude slum clearance programs by other agencies. It does provide relief to the greatest number of people in the least time and at minimum governmental expense. Benefits obtained from this action alone include better lighting and ventilation, replacement of outdoor toilets, elimination of rat-breeding areas, correction of structural defects, elimination of fire and accident hazards and creation in the occupants of a pride in clean living conditions.

## NOISE

Noise may be considered as disturbing sounds which interfere with work, thought, and rest. The degree of annoyance depends upon the frequency of occurrence, the absolute intensity, or loudness, the relative loudness, and the necessity for the noise. The tooting of automobile horns in cars parked at the curb to signal persons indoors is extremely annoying because it is unnecessary as well as discordant. A fire siren is discordant but may not be annoying because it is accepted as necessary. The steady hum of city traffic is ignored. Carpenters working together are not bothered by hammering noise but office workers nearby would almost certainly be disturbed.

Noise intensity is measured in decibels. This unit is that ratio of the sound being measured to the lower limit of audibility with the lowest hearable intensity taken as zero.[2] Table 25. Noise levels given off from specific sources are:

| Threshold of Annoying Sound | Decibels |
|---|---|
| Hammering on steel plate | 113 |
| Automobile horn | 102 |
| Riveter | 101 |
| Subway | 97 |
| Elevated train | 91 |
| Motor truck | 87 |
| Police whistle, street car, noisy passenger auto | 83 |
| Radio loud speaker | 81 |
| Passenger automobile | 65 |
| Ordinary conversation | 60 |
| Business office | 50 |
| Quiet private office | 30 |
| Whisper at 5 feet | 10 |
| Threshold of hearing | 0 |

Decibels measure the relative loudness of a sound to the physical ear. The physical intensity can also be measured. A definite relationship exists between the two scales, decibels being equal to 10 times the logarithm of the physical intensity. Examples are:

| Decibels | Physical Intensity |
|---|---|
| 0 | 1 |
| 10 | 10 |
| 20 | 100 |
| 50 | 100,000 |
| 100 | 10,000,000,000 |

TABLE 25

*Noise Intensities*

| Decibel | Intensity | Indicative Sound* |
|---|---|---|
| 0 | 0 | Just audible |
| 10 | 10 | Rustle of leaves |
| 20 | 100 | Whisper |
| 30 | 1,000 | Suburban street |
| 40 | 10,000 | Average dwelling |
| 50 | 100,000 | Commercial premises; quiet automobile |
| 60 | 1,000,000 | Ordinary conversation |
| 70 | 10,000,000 | Noisy street; loud conversation |
| 80 | 100,000,000 | Heavy urban traffic; loud radio |
| 90 | 1,000,000,000 | Pneumatic drill; motor cycle |
| 100 | 10,000,000,000 | Riveter at 35 feet; loud auto horn |
| 110 | 100,000,000,000 | Metal working shop |
| 120 | 1,000,000,000,000 | Airplane propellor |
| 130 | 10,000,000,000,000 | Painful sound |

* Phelps, Earle B., "Public Health Engineering", v.1, p. 185, John Wiley, and Sons, New York, 1948.

Winslow, C-E. A., et al., "Housing for Health", Science Press, Lancaster, Penna., 1941.

In large cities many complaints are made against various types of noise. They are usually directed against specific conditions at given locations and at a definite time. In 1930 a survey was made of the various types of noise complaints received in New York City. As shown in Table 25 the bulk of city noise is caused by traffic, auto horns, squealing brakes, street cars, whistles and radios. Following this survey an abatement campaign[3] was conducted with the enactment of laws against unnecessary horn blowing, use of radio after midnight, and noisy outdoor advertising. The results were a reduction in localized concentrations of noise in many sections of the city and appreciably lessened overall density.

Specific health hazards associated with noise are hard to find. Industry

has been unable to prove conclusively that high levels of noise interfere with production or produce extra fatigue. Deafness does seem to be associated with continued exposure to high noise levels. There does also seem to be some effect by noise on the psychological well being of people.

In many instances noise abatement is impossible but overall diminution may be accomplished by an educational program to enforce remedial measures similar to those cited above. Such a program is successful only if directed by a responsible governmental agency which may readily be the health department. Cooperation, not punitive measures, must be the keynote. City planning can assist by restricting noisy industrial or commercial operations to business or industrial zones. Substitution of less noisy vehicles, as busses for trolley cars, has helped materially in many cities. Educational measures among all groups of people—business and industrial, management and worker, parents, school children, motorists, delivery men—should lead to marked reductions in unnecessary noise.

## INDUSTRIAL SANITATION

The industrial hygiene program in its entirely is too extensive a subject to be discussed in this volume. It includes a thorough consideration of atmospheric pollution; various industrial hazards peculiar to certain jobs because of materials or equipment used or waste products resulting from the operations; and special problems of heating, lighting, noise, or ventilation. Part of the industrial hygiene program parallels the environmental sanitation activities of a health department as directed for the protection of the population at large. This section deals with that segment of the industrial hygiene program.

The working environment varies with the types of industries—that of a clothing manufacturing establishment is unlike that of a foundry. There are, however, some problems in sanitation which are similar in all industries and which might be termed "personal facilities" or items of housekeeping. These include lighting, toilet and lavatory facilities, drinking water supply, lockers, cafeterias and lunch rooms, and waste disposal.

### Lighting

Poor lighting is a factor in an appreciable percentage of industrial accidents. In addition it causes eyestrain, serves to mask poor plant housekeeping, and reduces the efficiency of employees. When lighting is made adequate less material is spoiled, workrooms are kept neater and more orderly, and employee-management relations generally are better. Many manufacturers have found that good lighting pays direct monetary dividends greater in amount than the cost of the lighting installations.

Appraisal of existing lighting in an industrial plant is not difficult. The

unit for measuring the intensity of illumination is the "foot candle." It is the illumination received at a surface one foot distance from a light of one candle power. Very convenient light meters, small and inexpensive, are now available for making light intensity measurements. In an industrial plant, measurements are made at the working plane. Standards of illumination intensity have been compiled giving the number of foot candles which

TABLE 26

*Recommended Levels of Illumination for Industrial Interiors**

| | Foot-Candles Recommended |
|---|---|
| Aisles, stairways, passageways | 5 |
| Automotive Manufacturing: | |
| Assembly line | 50–100** |
| Bakeries | 20 |
| Cloth Products: | |
| Cutting, inspecting, sewing— | |
| Light goods | 20 |
| Dark goods | 100 and up** |
| Forge shops and welding | 10 |
| Jewelry and watch manufacturing | 100 |
| Laundries and dry cleaning | 20 |
| Locker rooms | 6–4 |
| Offices: | |
| Close work | 30 |
| No close work | 10 |
| Distribution of mail in post offices | 20 |
| Drafting room | 30–100** |
| Paint manufacturing | 10 |
| Polishing and burnishing | 15 |
| Receiving and shipping | 10 |
| Toilet and wash rooms | 6–4 |
| Warehouses | 5 |

* Based upon recommendations of the Illuminating Engineering Society.

** Includes generalized lighting of 20–30 foot-candles and the balance in localized specialized lighting.

should be furnished for various types of occupations. Naturally persons doing fine needlework require a great deal more light than those engaged, for instance, in wrapping packages. These levels are based upon empirical formulae or practical considerations. Table 26.

Many plants depend on natural illumination the greater part of the day. When daylight is used the number of foot candles required is approximately twice as many as prescribed for artificial lighting. To obtain the full benefit of daylight illumination, ceilings and upper portions of the rooms should be of a light color with the lower portion somewhat darker so as to give a

restful contrast to the eyes. If opaque window shades are used they should be fastened to and raised from the bottom in order to obtain a maximum diffusion of light into the upper interior of the room. At times, ribbed glass is used in windows, giving a more even distribution of light. Windows and skylights should be washed frequently since accumulations of dirt cut down the amount of otherwise available light.

Artificial illumination, as used in industry, can be classified as general and local. In most plants a combination of both is used. General lighting, as the term indicates, is used for illuminating the entire workroom. Local lighting is used to augment this system at work places where higher illumination intensity is required. To obtain the full benefit of the available illumination fixtures, reflectors, globes and bulbs should be cleaned periodically. A good lighting system loses its effectiveness by accumulations of dust and dirt.

One of the greatest annoyances in illumination is glare. It may be defined as brightness of such intensity within the field of view as to interfere with vision or to cause discomfort. Endeavoring to work with an unshaded electric bulb within the vision range is extremely uncomfortable and at times painful. When direct lighting is used deep reflectors which entirely hide the lamp filament eliminate glare, provided the direct light is not reflected into the workers' eyes from shiny surfaces at the working plane. Indirect and semi-indirect lighting systems, while requiring more power for the same illumination intensity as direct illumination, eliminate glare and give a more even distribution of light. Indirect lighting is obtained by directing the light from the bulb to the ceiling or upper walls without any rays shining directly on the work areas. The whole ceiling and upper walls thus become light sources, with relatively low intensity of light, from any portion.

Whenever illumination levels rise above 40–50 foot-candles, the quality of the lighting becomes extremely important. There is no evidence that lighting levels much in excess of those recommended for any operation will do harm, provided the lighting is done satisfactorily. As higher levels of illumination are attained elimination of glare, either from rays of lights reaching the eyes directly from the luminaire or reflected from surfaces, becomes a basic requirement. Likewise, the contrast between light and dark portions of the field of vision must be held to certain well established minimum ratios. Good lighting requires great skill and should not be attempted by any one not trained in the fundamental principles of illumination.

Fluorescent lamps have found wide use for several reasons. One is that greater light levels can be attained by this method of illumination than with the filament bulb without increasing the power input. Closely associ-

FIG. 93. School room lighting. (a) Incorrect. (b) Correct. (Courtesy, General Electric Co.)

ated with this advantage is that of power cost, that for fluorescent tubes being less than for the filament type of bulb. From a physiological point of view, the fluorescent tube has a distinct advantage in that the light produced is emitted throughout the entire surface of the tube thus cutting

down on the unit area concentration of illumination. Direct glare from fluorescent tubes is much less likely than from the filament type of luminaire. Detailed studies indicate that there is no physiological damage produced by constant use of fluorescent lighting.

## Toilet and Lavatory Facilities

In many plants of small size employing fewer than 100 persons, the sanitation of toilet and lavatory facilities is frequently neglected. With

Fig. 94. Industrial washing facility, Milwaukee, Wis. (Courtesy, Bradley Washfountain Co.)

janitor services unavailable no one is responsible for keeping toilets and washrooms in a sanitary condition.

Adequate toilet facilities in the ratio of one to about every 10 persons should be conveniently located in rooms partitioned off entirely from work-rooms. The rooms should be provided with proper lighting and ventilation and be maintained in a clean sanitary condition at all times. One third of the male toilet facilities may consist of urinals. Washing facilities should be provided on a ratio of 1 wash bowl or space to every 10 persons, and hot water must be made available, especially where workers come in contact with any harmful materials or with food. Bathtubs or showers, 1

per 15 persons, should be provided where the employees are exposed to excessive heat or to skin contamination with poisonous, infectious or irritating material. Individual paper or cloth towels and soap should also be available.

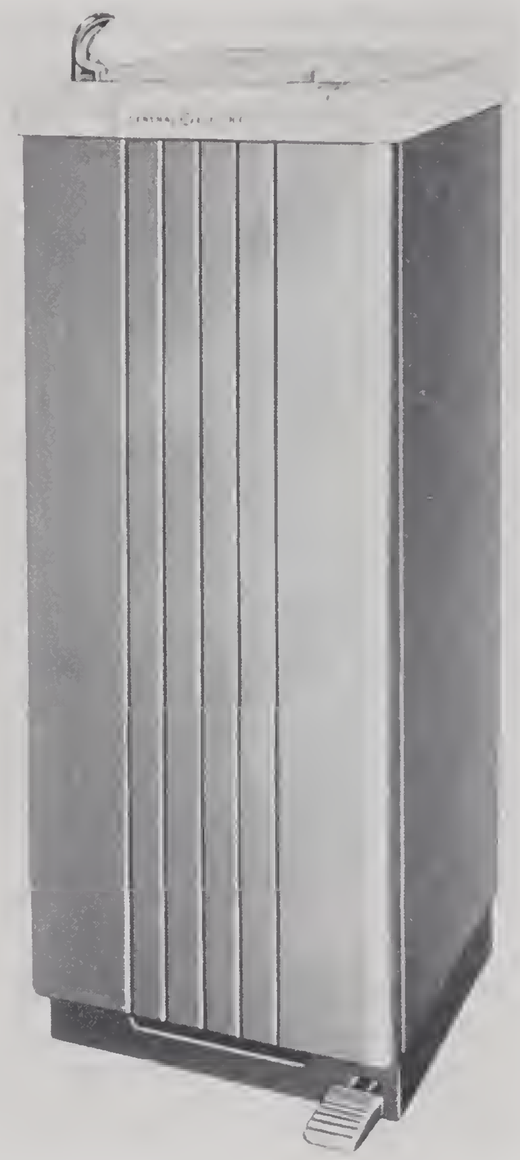

Fig. 95a. Modern drinking fountain delivering cold water. (Courtesy, General Electric Co.)

## Drinking Water Facilities

The drinking water supply in factories should meet recognized sanitary standards for potable water and should be accessible at convenient locations throughout the plant. If the water is cooled, it should be to a temperature of from 45°F. to 55°F. at the outlets. No cross connections between the drinking water and any other supply used for industrial purposes should exist. Piping systems should be painted distinctive colors so that the potable

and non-potable water, steam, and other liquid systems can positively be identified.

Individual paper cups should be provided except where sanitary drinking fountains are installed. Drinking fountains should be provided on the basis of 1 for every 75 employees. The construction of the fountain should be such that it minimizes disease transmission hazards. The American Standard Specifications for Drinking Fountains[42] covers this in detail.

### Lockers

In many industrial establishments the personnel require lockers for the storage of street clothing and personal effects. Where workers come in contact with harmful materials, lockers having two compartments, one for street and one for work attire, are preferable to the single-compartment locker. Lockers should be sealed to an impervious floor or there should be a space of 4 or 5 inches under the locker to permit floor cleaning. Sloped tops prevent the accumulation of dirt. Lockers are usually made of metal and are provided with openings to permit the circulation of air through them. At least $4\frac{1}{2}$ square feet of floor area should be allowed per locker. Each person should be held responsible for the cleanliness of his locker. When dressing rooms are provided they should have adequate light and ventilation, be cleaned daily, and, if for women, be equipped with a cot or couch.

### Cafeterias and Lunch Rooms

Some factories have complete cafeteria service for employees at reasonable prices, others provide a separate room for the use of the workers during the lunch period, and still other plants permit the personnel to eat their lunches at work benches. The last procedure should be discouraged in non-hazardous occupations because of the possibility of attracting insects and rodents throughout the plant. In hazardous occupations this practice should be strictly prohibited. Where a separate room is furnished employees for eating lunch, it should be adequately lighted and ventilated and furnished with sufficient tables and chairs. Receptacles for refuse and garbage should be conveniently located and provision made to keep the room in a clean condition. Strict attention should be given to the proper refrigeration and preparation of all food served in the cafeteria. The operation of a factory cafeteria or lunchroom should conform to the standards established for public restaurants. Particular attention should be given to the supervision of lunch wagons and canteens that serve many industrial areas.

## PUBLIC BUILDINGS

Sanitary facilities for office buildings, theaters, public rooms of hotels, railroad stations, schools, and municipal buildings are usually covered in

the local plumbing or building code. Accepted minimum requirements for toilets and lavatories in office or public buildings call for approximately 1 of each for every unit of 15 people in the building. In toilets for males, urinals may be substituted for water closets to the limit of one third the required water closets.[42]

Sanitary drinking fountains at the rate of 1 per 75 people should be installed or individual paper cups should be supplied. The health department should make inspections of these buildings to note their cleanliness and obtain compliance with local standards.

FIG. 95b. Testing plumbing equipment, Bureau of Engineering, Chicago, Ill. (Courtesy, E. J. Zimmer.)

Consideration has been given to dangerous cross connections to the water supply, page 166. These may be classified as direct or indirect. Many papers have been published relating to faulty plumbing and disease hazards.[20]

The indirect type of cross connection results whenever a water supply plumbing fixture is located so that it can become submerged in sewage or contaminated water. Even if the pipe rises above the top of the fixture it is possible to draw the contaminated water into the drinking water supply when a vacuum is formed in the domestic supply pipe. This form of cross connection, based on the principle of siphonage, exists in many of the present types of plumbing fixtures, such as wash basins, bath tubs, laundry trays, instrument sterilizers, bedpan washers, dish washers, wash-tanks in soda fountains and in numerous kinds of industrial equipment. When inlets are, or become, submerged in fixture contents and a vacuum occurs in the

piping system, part or all of the contents are siphoned into the drinking water. These occurrences will take place when the fixture control valve is open under failure of pressure in water mains due to a break, or to a great demand for water for fire fighting or in draining a building supply for making repairs.

One type of indirect cross connection which is particularly hazardous because of the possibility of siphoning sewage into the drinking water piping, is entailed in the flushometer valve so widely used for toilets. This particular type of valve will not hold pressure and opens when that of the regular supply is reduced or when a vacuum occurs in the line. If such a situation exists during a stoppage in the toilet bowl, the inlet becomes submerged and some of the bowl contents will be siphoned into the water supply lines. In some type of toilet bowls this stoppage is not necessary to cause trouble.

From the discussion given, it is apparent that the prevention and elimination of indirect cross connections are of sanitary importance. Whenever possible water supply inlets should terminate above the rims of fixtures forming complete breaks between the drinking water and contaminated water. All fixtures should be provided with vacuum breakers to prevent back-flow syphonage and most cities require their installation. Plumbing fixtures sold today are usually designed with vacuum breakers.

Facilities in buildings of public assembly such as theaters and railroad stations are based upon the average number of persons using them. Minimum standards are:[42]

| | |
|---|---|
| Water closets | 1 for 1–100, 2 for 101–200, 3 for 201–400 males or females. Over 400, add 1 closet for each 500 additional males and 1 for each additional 300 females. |
| Wash basins | 1 for 1–200, 2 for 201–400, 3 for 401–750. Over 750 add 1 wash basin per each 500 additional persons. |
| Urinals | 1 per 200 for first 600 males. One urinal per each additional 300 males. |

## RAILWAY TRANSPORTATION

Interstate railroad transportation has been vitally concerned one way or another in efforts to prevent the spread of disease from one section of the country to the other. In the early days of railway transportation many types of quarantine were established by the states to regulate trains coming from disease infected areas. The multitude of regulations usually resulted in much hardship to the passengers. This chaotic situation continued until 1894 when the first interstate quarantine regulations were adopted. From this period until about 1915 there was a practically unending stream of state legislation concerning railway sanitation and the fumigation of passenger cars. These laws were frequently at variance from

state to state and general compliance was difficult. In 1913 a committee of the American Medical Association on railway sanitation presented a code which was promulgated as the Interstate Quarantine Regulations of 1916. In 1920 a standard railway sanitary code was adopted by the Conference of State Health Authorities and in 1921 this recommendation was made part of the quarantine regulations.[41, 44]

The United States Public Health Service, which is now responsible for public health supervision of all interstate transportation facilities, has recently developed a sanitation manual for public conveyances "to provide health agencies and carriers with information upon which to base procedures and as a guide in the administration of the interstate quarantine regulations."[49]

These regulations are applied to interstate carriers through cooperation between the United States Public Health Service and the various state departments of health. The water supplies are certified by the state health agencies. The general sanitary conditions of the railway cars, stations, etc. are passed upon by the United States Public Health Service through its district engineer with issuance of the final certificates of approval by the Surgeon General.

Only approved water supplies should be used for supplying drinking water to railway cars or busses, and the water hydrant should be properly located and designed to assure protection against contamination. This is accomplished by locating the hydrants above the rails in coach yards and, if in a box at station platforms, by having the cover well protected. They must also be distinctly marked and all outlets protected against contamination. Hoses, used to replenish water supplies in cars should be stored in a clean receptacle and protected from contamination at all times. Tank filling and hydrant ends of hoses should be protected by a rigid 6 inch diameter disc fitted 8 inches from each end to keep the hose opening from touching the ground. All water lines must be flushed immediately before filling the car tanks. Water hoses must not be used for any other purpose than car watering.

Ice used for cooling drinking water or for use in dining, buffet, or club cars should be stored in clean rooms and all buckets, carts, and other containers used in its handling should be painted white and their use restricted to this purpose. The ice for drinking water should be placed in a compartment completely separated from the drinking water. This arrangement prevents any possible pollution of the water by dirty ice.

The Public Health Service Code also provides that all railway cars should be kept reasonably clean and in a sanitary condition. All coaches must be brushed and swept at the end of each round tip, or at least once every day they are in service, and they must be thoroughly cleaned weekly.

Discharge of wastes from toilets is prohibited while cars are standing in a station. Violation of this regulation is prevented by keeping toilet doors locked while trains are in the stations. Sleeping cars parked to receive passengers are provided with cans placed beneath the toilet hopper to receive wastes. The cans must be removed before the train departs. Emptying, cleaning, and storage of cans require rigid regulation.

The discharge of toilet wastes along the right of way from trains en route is under study.[39] Macerating and subsequent sterilizing with heat of toilet waste appears to be practical. However, Maxey[19] was unable to discover evidence that waste pollution along rights of way produced unusual incidence of infection among people living adjacent to or working on the tracks, or among consumers of water supplies possibly polluted by these discharges. In the light of this study the requirement of the railroad code that toilets be locked while passing over watersheds warrants further study.

Food supplies and service must conform to the standards previously discussed under restaurant sanitation, page 58. Confined storage and working space renders satisfactory operation more difficult than under fixed conditions. The danger of disease transmission through food is particularly acute in railway diners since the patrons of dining cars may be traveling to widely separated areas. Food-handler health and personal habits are therefore extremely important.

The standard Railway Sanitary Code prohibits a person suffering with plague, cholera, smallpox, typhus fever or yellow fever from traveling on railway trains. Individuals suffering from certain other communicable diseases, such as diphtheria, measles, scarlet fever, etc. may travel if placed in a compartment separate from other passengers and if accompanied by a qualified nurse or other attendant. When traveling, communication with the compartment must be restricted to the minimum consistent with the care and safety of the patient. All dishes and utensils shall be sterilized and all discharges from the patient must be wrapped in paper containers and burned.

General sanitation restrictions are set forth as to the handling of these patients, such as the protection of beds by rubber sheets and disposal of excreta.

If a person is suspected of an infectious or contagious disease, the conductor or other authorized agent of the railroad must notify the nearest health officer who shall immediately proceed to the train at the most convenient point for the purpose of diagnosis. In accordance with the judgment of the health officer, the patient shall either be allowed to proceed under restriction as set forth above, or immediately removed to a local hospital for isolation.

### Bus Transportation

Since inter-state busses usually do not carry drinking water or serve food and are not provided with toilets only that part of the code requiring cleanliness and transportation of persons suffering from certain diseases applies. Rest stops, restaurants, and terminals are under local health jurisdiction. Sanitary regulations similar to those required for restaurants should be enforced. Rigid control of eating places is particularly important because of the hazards introduced by the sudden influx of passengers which puts undue strains on food handling and dish washing equipment. It must be remembered that these patrons too may go to widely distributed areas.

## WATER TRANSPORTATION

The disposal of wastes and protection of water supplies, mess (restaurant) sanitation, and rodent control are the environmental sanitation problems of greatest importance in water transportation. Ocean liners obtain drinking water from certified land sources, or use distilled water from the ship's condensers. Ships navigating in inland fresh water streams usually use shore water sources or they may draw their own supply directly from the lakes or rivers. Most inland waters may be polluted by the bordering towns or the water may be contaminated by sewage discharged by boats in transit.

The same general principles that guide the health department in working with any group hold also for passengers on water craft, but certain phases of sanitation have particular importance or peculiar problems. Regulation of vessels in interstate or international movement is a responsibility of the United States Public Health Service.

Water taken from sources ashore should conform to the standards and be handled under conditions similar to those set forth in the Railway Sanitary Code. A safe supply for use aboard ship should be assured. On the other hand, it is important to protect shore supplies against possible contamination by sewage discharges from ships. Ships should not be allowed to discharge sewage or empty their bilge water near the inlets to municipal water systems. Likewise, discharge of sewage while ships are in port should be prohibited. This means that adequate storage tanks must be provided for the retention of sewage while ships are in port.

If the drinking water aboard ship is not obtained by distilling sea water, (a sterilizing process itself) the water should be treated to render it safe. Chlorination usually will be adequate since most water taken aboard will be free of gross contamination. Additional treatment, such as filtration through pressure filters, should be provided if highly contaminated water must be used. Storage of treated water aboard ship must be done in such a manner that contamination of the supply will be avoided. Sea water is used

for many purposes. Water lines carrying potable water should be marked clearly to differentiate them from lines carrying sea water or other non-potable supplies. If sea water is taken aboard for potable uses ports should be placed well forward of any sewage or bilge outlets to prevent contamination of the intake water by discharges from the ship.

Mess sanitation should follow the same general pattern of restaurant sanitation ashore. Quarters on shipboard frequently are cramped so that space for equipment may be inadequate for normal types of dishwashing facilities and other cleaning equipment. Fortunately, steam is usually available for sterilizing purposes. Refrigeration facilities must be adequate both in space and operation. Since food sufficient for the journey must be taken aboard at the last port of call, storage of perishable foods for extended periods of time must be anticipated. The usual precautions taken for the elimination of insects and rodents should be satisfactory on shipboard.

The shore communities must be protected against certain hazards present in sea traffic. One of these is rodent importation. When ships are tied up at port precautions should be taken to prevent rodents from getting aboard ship *and* off ship. Some of the historically famous outbreaks of disease have been traced to the migration of rats via ships. Educational efforts with ship builders have resulted in construction that eliminates from ships many of the rodent harboring spaces formerly part of every ship. Disinfestation by use of a suitable fumigant may be necessary in heavily infested ships. A continuing rodent trapping and poisoning campaign should be part of every ship routine. Rodent infestation of ships can be eliminated with suitable precautions. Trained inspectors can tell within a narrow range of error the prevalence of rodents on shipboard.

Garbage disposal on shipboard is usually simple—and effective. The garbage from galleys is thrown overboard at frequent intervals. This method is satisfactory while the ship is at sea. It is not satisfactory when the ship is in port. When in port the garbage should be stored and held until it can be discharged overboard without creating a nuisance or else arrangements should be made for its collection by one of the normal garbage collection services on shore.

Education of crew and officer members of ship staffs should be part of every vessel sanitation program.

## AIR TRANSPORTATION

Water, milk and food supplies should conform to the same sanitary requirements as for interstate railroad traffic. Chemical toilets are used in flight for sewage disposal. Proper disposal of wastes on land and cleansing of receptacles is an important operation. Port terminal facilities should

conform to those of railway stations. Transportation of persons with infectious or contagious diseases should be prohibited. The United States Public Health Service is responsible for the supervision of environmental sanitation in all planes and at all terminals in interstate and international commerce.

The speed of air transportation is so great that extreme precautions must be taken to prevent the importation from abroad of disease either by infected persons or insect disease vectors.[48] Specific requirements have been established for the vaccination of persons coming from or passing through areas in which certain diseases are prevalent. These regulations, for the most part, have their basis in international quarantine requirements. From a sanitation viewpoint, elimination of any insects that might serve as the link between an area of disease prevalence and one free of the disease is highly important. Mosquitoes and certain of the biting flies are the insects of greatest importance. Definite requirements have been established calling for the disinfestation of aircraft before leaving ports and again immediately upon landing at port. One of the standard insecticides, pyrethrum, is used in this treatment. In addition, in parts of the world where certain diseases may be endemic, such as malaria in certain parts of Africa, precautions are taken to rid the area of the airport and surrounding section of the insect vector. The rapid, international reporting of the incidence of the more dangerous diseases makes easier the prevention of disease transmission by common carriers.

## CAMPS

Summer camps, motor courts and trailer camps are usually operated under permits from the state health authorities. In some instances trailer camps and motor courts are under local health jurisdiction. Summer camps are frequently located in remote areas where there is little or no local health department activity. Certificates of inspection and approval are posted at the camp as evidence of this supervision.

Of most importance in any camp operation is a safe water supply, a safe milk supply and food service, satisfactory methods of sewage and waste disposal, insect control, and sanitation of bathing beaches or of swimming pools. Organized camps conducted during several months of the year for the benefit of children and young people frequently provide well supervised methods of sanitation particularly in those camps under the supervision of national groups of the Boy or Girl Scouts, the Campfire Girls, or the Salvation Army. The numerous tourist camps and the increasing number of trailer camps in some states have required the application of sanitary methods which were found to be practical and effective in the older well

organized camps. Many trailer and tourist camps are located within municipal limits and so are accessible to municipal water supply and sewage disposal facilities and even garbage collection services.

Summer camps present special problems to the health department. These establishments are usually located in places graced with natural beauty, if such is possible. This frequently means that they are outside the limits of normal city sanitary facilities such as water supply and sewage disposal. Their isolated location may also mean that supervision by health departments is difficult. The fact that the usual patrons of camps are transients who may make their next stop 200 or more miles distant complicates the difficulty of the health department staff. This mobility makes control of infected individuals difficult.

Many people utilizing the services of camps are out of their usual environment which may make them unusually susceptible to infection or they may be confronted with situations unfamiliar to them. Many campers and tourists are not aware of the fact that safe water supplies and food services must be especially provided and do not spring into existence. Likewise, many of them may be exposed to infections strange to their normal contacts, finding them particularly susceptible to infection. The whole atmosphere of camps and also of motor courts and trailer camps is likely to be one of relaxation, of a picnic frame of mind. Under these circumstances otherwise fastidious, or at least sensible, individuals are likely to shrug off conditions they normally would not countenance, as part of the vacation, "roughing it" life. Obviously, disease organisms do not recognize any moratorium during such periods.

The best way for the health department to supervise the sanitation conditions in any camp is to have an alert camp staff that understands its responsibilities for the health of the campers and is anxious to fulfill those responsibilities. Actually, there are no special problems of sanitation in camps. With proper instruction any conscientious staff should be able to operate a camp satisfactorily from the public health viewpoint.

The water supply should conform to those principles discussed in Chapter VI. It is important to bear in mind the fact that *all* water should meet satisfactory standards. If auxiliary supplies are used along trails on overnight trips, those supplies should meet the same rigid requirements that the main supply meets. The same precautions should be applied to human wastes disposal, namely, that the same degree of care should be used in disposing of wastes on the trail as in camp. The individual should be taught to defecate in scooped out holes in the ground and then use the removed earth to cover the wastes. Since overnight trips usually follow trails frequently used, permanent facilities such as privies, should be erected at

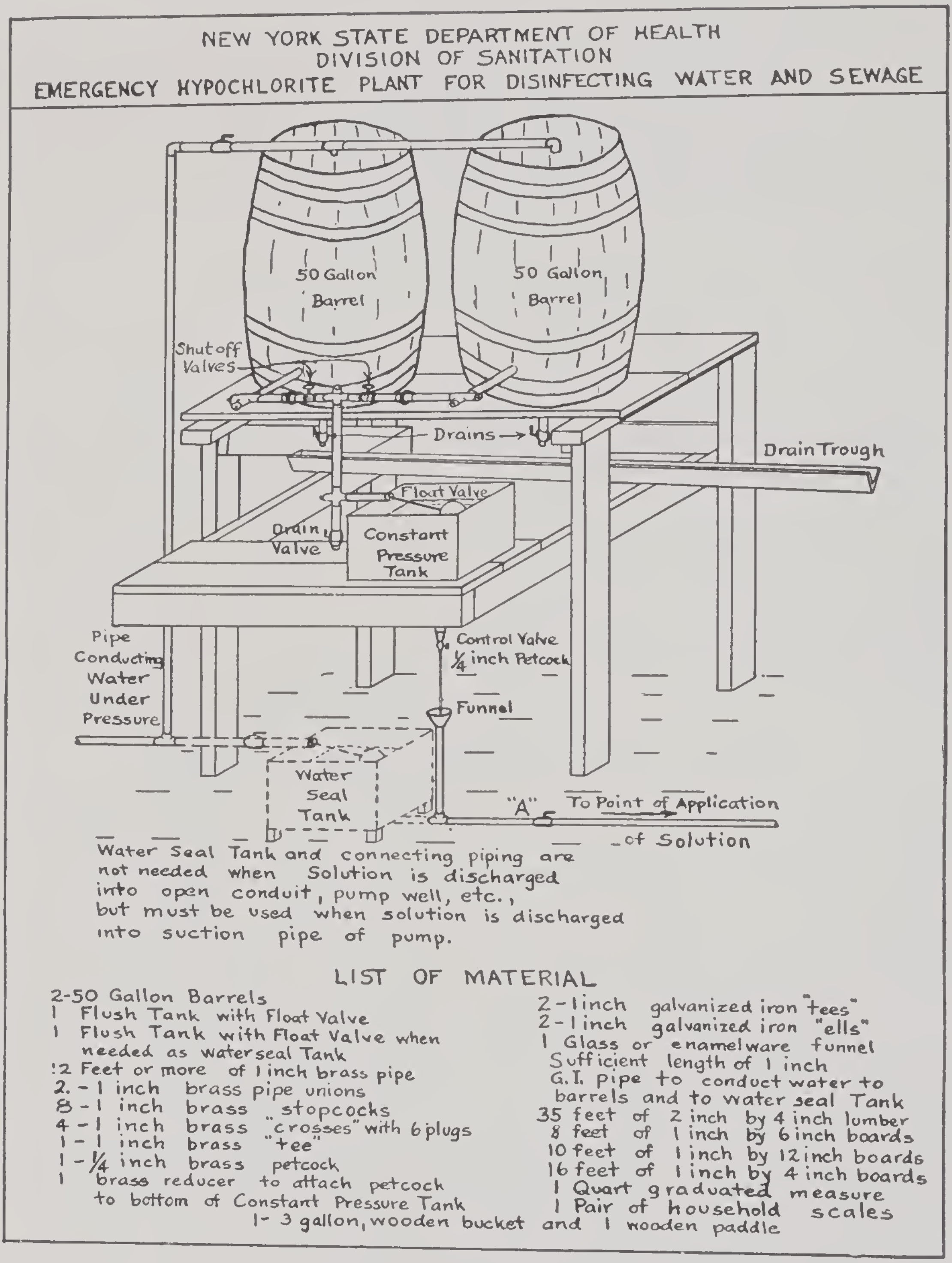


FIG. 96. Emergency hypochlorite plant for disinfecting water and sewage. (Courtesy, Charles R. Cox, New York Department of Health.)

the overnight camping spot. Hand-washing facilities, however primitive, should be part of any permanent waste disposal installation.

Mess sanitation should follow the same methods outlined in Chapter IV. There is no reason why the same quality of food preparation, service and storage demanded in our best city restaurants should not be followed in

camps. The same supervision of the health of the kitchen staff should be given as recommended for urban restaurants. The wastes from the messes are just as good fly-breeders and rodent feeders in rural areas as they are in city environments. Therefore, the same precautions should be used in proper disposal of garbage. It is probable that burial will be used to a great extent although many camps make arrangements locally for collection by a scavenger.

Disposal of wash and bath water may provide a special problem. Ground conditions for absortion of liquids are frequently poor in camping areas in mountainous regions. For this reason, most camp directors do not want to increase the problem of human wastes disposal by using the septic tank and tile field, or whatever other method may be used, for the disposal of large quantities of liquids initially of little hygienic importance. There is some merit to this thought but a short period of experience will demonstrate the fact that the reasoning does not take all factors into consideration. Waste kitchen or bath water can and will produce nuisances of great proportions. The decomposing organic matter in the water will produce unpleasant odors, the appearance of the pools of water is offensive and, most important of all, the accumulations of water will provide ideal breeding places for mosquitoes and flies. Except for toilets in the same building with showers, it is probably best to dispose of kitchen and bath water separate from the human wastes. Of course, if human wastes are added to shower water then the whole quantity must be treated as human wastes. If septic tanks are used, a grease trap should precede the tank. The tile field should be designed on the generous side rather than the skimpy side. (It is hard to convince the kitchen personnel that they should not conserve wash water if they can see that the disposal field for the waste waters is overflowing.) If the ground water level is so high that absorption cannot be obtained in the ground it may be necessary to construct a contact bed above the ground water level and discharge the effluent from the bed into some nearby stream. The disposal of human, and kitchen and bath wastes usually presents a special problem for each camp. Expert help should be provided to solve each situation. The health department should be prepared to give that help.

Insect and rodent control must be adjusted to local conditions. The campers will generally demand good control of insects. Rodents being somewhat less obvious may not fall under demands of the campers and so the camp staff must be alerted to the need for rodent eradication. Methods for insect and rodent control are given in Chapter XIII. These methods can be applied readily to any environment and set of circumstances. Needless to say, if there are insects of local importance special measures should be taken to eradicate them. Ticks and Rocky Mountain Spotted Fever, and

deer flies and tularemia are examples of special problems demanding special attention.

Swimming pools and bathing areas are discussed in Chapter XI.

One of the most important factors in maintaining satisfactory conditions in a camp is absolute, unquestioned placing of responsibility for sanitation on some specific person. It is not sufficient to assume that the director or the camp physician or nurse will supervise the sanitary facilities. The job must be given to some one person in terms that permit no question of responsibility. Furthermore, definite arrangements should be made for an understudy to take over should the person primarily responsible be away from camp. The fact that the director of sanitation had been in town for 2 or 3 days may be a reason for the dish washing being done in a careless manner. The hazards from improperly washed dishes do not evaporate with the absence of any member of the camp staff. Unless someone knows he is responsible for the sanitary condition of the camp, and unless each member of the camp staff knows that also, a condition of "everyone's responsibility is no one's" is likely to result. The camp physician or nurse, if equipped with the proper knowledge and a desire for the assignment, should make a good director of camp sanitation.

## MOTOR COURTS AND TRAILER CAMPS

Motor courts should be considered on the same basis as any living accommodations for transient populations. Since these are public facilities, one of the requirements for a municipal license and health department approval should be compliance with the basic concepts of good environmental sanitation already discussed. The water supply should be adequate and safe; sewage and garbage disposal should be satisfactory; rodents and insects should be kept under control at all times; and the general surroundings of the courts should be kept clean. If dining facilities are provided they should meet the requirements of any public eating place.

Once again, the importance of knowledge must be stressed. If the operator of the courts knows what is required and why it is required, particularly as it may affect his business, the health department will find its job of supervision much easier. As with camps, someone must be responsible for the sanitary conditions of the area. This person should be designated when application is made for a license to operate the motor court.

### Trailer Parks

The increased amount of travel by automobile has accounted for the growing number of trailers. The transitory nature of trailer life presents to public health officials special problems. Trailer inhabitants create many

of the problems discussed in the early part of this section. They have a pioneering spirit, they want to see new places, they are prepared to accept much cruder services than those they normally receive. On the other hand, they may not be equipped to evaluate the special conditions under which they may be living. Unfortunately, the operators of many trailer parks are equally ignorant of the requirements of the trade they have undertaken.

Fundamentally, the problems of good sanitation for a trailer park are the same as those for a camp or motor court.[47] The water supply must be safe and adequate for all sanitary needs. There must be an allowance of at least 50 gallons per capita per day, based on the maximum capacity of the camp. Ample provision should also be made for fire protection. If a separate system is used for fire protection it should be piped separately and the system should be distinctively painted and plainly marked. There should not be any outlets of such a size that the usual trailer connection might be used. All outlets should be separate and apart from those for potable water. A camp connection to the potable water supply should be available at each trailer parking spot. The connection should be such that the open end of the pipe is at least 4 inches above the surrounding ground so that pollution from that source will be minimized.

Connections to the water supply line in the trailer should be protected against contamination or pollution while the trailer is en route. The distance in the trailer between the water connection and the sewer outlet should be at least four feet.[43] Piping connections should be such as to prevent back-siphonage through any of the trailer fixtures into the water systems.

If water connections are not made at each trailer parking area suitable common outlets conveniently located must be available for the trailer owners. It is better to require each trailer group to use its own containers in transporting water than it is to provide common containers which may become dirty through frequent use or lack of a strong feeling of responsibility on the part of campers to keep receptacles clean.

Sewage disposal must be provided for with a connection to the sewer for each trailer or else by the provision of suitable hopper connections and cleansing facilities where the toilet receptacles of the various trailers can be emptied, washed and sterilized. Camp toilet facilities can also be provided for exclusive use of trailer inhabitants. The individual sewer connections are preferable. The camp connections to the sewer should be at least 4 feet from the camp water connections and must be fly-tight. Leakage of any sewage onto the ground should not be permitted.

If individual trailer sewer connections are not provided the camp should be held responsible for prevention of the use of the trailer toilet system unless it is connected only to the interior trailer receptacle. The safest pro-

cedure prohibits the use of any trailer toilet system and requires use of camp toilet facilities.

Adequate washing, bathing, and laundrying arrangements should be provided, including an ample supply of hot water. The following facilities should be available in the ratios indicated:

| Water Closets Required | | | Urinals | | Lavatories | | | Tubs or Showers | |
|---|---|---|---|---|---|---|---|---|---|
| Persons | Male | Female | Males | Fixtures | Persons | Fixtures M* | Fixtures F* | Persons | Fixtures |
| 1–10 | 1 | 1 | 1–30 | 1 | | | | 1–7 | 1 |
| 11–25 | 2 | 2 | 31–60 | 2 | 1–15 | 1 | 2 | 8–15 | 2 |
| 26–40 | 3 | 4 | 61–100 | 3 | 16–30 | 2 | 3 | 16–25 | 3 |
| 41–60 | 4 | 6 | 101–150 | 4 | 31–50 | 3 | 4 | 26–35 | 4 |
| 61–80 | 5 | 8 | | | 51–75 | 4 | 5 | 36–45 | 5 |
| 81–110 | 7 | 11 | Over 150 add 1 for each add'l 50 males | | 76–100 | 6 | 7 | 46–55 | 6 |
| 110–150 | 9 | 13 | | | 101–125 | 7 | 9 | | |
| Over 150 add 1 add'l closet for each 25 males and 20 females add'l. | | | | | Over 125 add 1 lavatory for each 20 add'l males and each 15 add'l females. | | | Over 55 and not over 200 add 1 tub or shower for each 10 persons. Over 200 add 1 tub or shower per each 20 persons. | |

* M—Male; F—Female.

These facilities should be so located that no part of the trailer area would be farther than 100 feet from any of the units. If any special hazard exists in the area because of insects or rodents the operator of the park should be required to take necessary precautions to protect the tourist from exposure to them. Adequate facilities should be provided for the storage of garbage in water-tight, covered cans, and for a suitable disposal system. The director of the park should also be held responsible for the maintenance of clean conditions throughout the camp. If a restaurant is operated in connection with the trailer park, it should conform to the requirements of any other restaurant. The disposal of all sewage from the park should be in accordance with principles already discussed.

Responsibility for the overall sanitary conditions of the trailer park should be assigned to a specific employee. The health department staff normally deals with the park management through this individual.

It must be remembered that trailer parks are not permanent residences and that many cities now limit the period permitted in residence. These periods vary from 90 days in any 6 months to 120 days in any year.[47]

## CONCLUSIONS

This chapter has dealt with the special problems that may confront the public health worker in his contacts with the environment around him. Much of the information is based upon technical knowledge. On the

other hand, much is based upon common sense supported by a modicum of scientific knowledge. The problems that have been touched here are those that frequently confront all public health people in their regular contacts with the public. Understanding the public health significance of these portions of the sanitation program is the responsibility of every public health department.

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## Chapter XIII

# INSECT AND RODENT CONTROL

Insect-borne diseases are well known and widespread. History has many times recorded the effects of plague and typhus fever. The fact that the mosquito thwarted the French in their efforts to build the Panama Canal is generally known. This apparently insignificant arthropod has often dictated the story of mankind. Moreover the relationship of disease to man's development is not a matter of ancient history. During World War II malaria, until it was controlled, proved to be our worst enemy in certain theaters of operation. Vast areas of the earth are subjected today to a primitive civilization because of the inroads of diseases carried by uncontrolled insects on the public health and economic life. Extensive areas of Africa are totally undeveloped because of the devastating effects of certain flies.

Rodents, particularly rats, play their part in the spread of insect-borne diseases by serving as hosts for certain insects, or as the reservoir of the causative agent of some diseases. In addition, the economic cost of their destructive habits is measured annually in millions of dollars. The eradication of certain insects and rodents is of prime importance in any public health program.

## INSECT-BORNE DISEASES

Dunham[9] has classified an insect-borne disease as one transmitted "when a blood sucking insect is the only or is the usual agent by which the etiological organisms are transmitted from person to person or from animal to man." Several such insects and the diseases they carry, of importance in the United States, are listed in Table 27.

The usual chain of infection is man—insect—man. Sometimes another animal becomes a part of the chain, as does the rat when it serves as the normal host for the flea. In some cases man is only an incidental or accidental link in the chain. Such is the case in Rocky Mountain spotted fever. The insect vectors of disease become infected by sucking blood from persons or animals carrying disease organisms in their blood streams.

The infection is subsequently returned to man through the bite of the infected insect and at that time the organisms are injected into man's tissues with secretions from the salivary glands or from material regurgitated from the digestive tract of the insect. In some instances the skin becomes contaminated with insect feces or crushed bodies of the insect and inoculation occurs when the feces or body parts are scratched or rubbed through minute lesions into the skin. Some disease organisms apparently can enter through unbroken skin.

The distribution of insect-borne diseases is directly related to the prevalence of the insect and animal species implicated in transmission of the diseases. Consequently these diseases are present only in areas where specific insect or animal species are indigenous and where environmental conditions are favorable to their continued existence. When animal hosts, such as rats, are involved the prevalence of the disease is governed by the incidence of the animals and the accessibility of the host animals to the infecting insects. It is usual to find individual species of a genus active in the spread of disease and other species of the same genus not involved.

Insect-borne diseases are controlled by the destruction of the insect or animal host at some stage of its life cycle; by making the environment unfit for breeding or continued existence of the adult vectors; by destroying the infective organisms in man to prevent the infection of insect vectors; or by protecting infected individuals from the bites of insects during the infective stages of the disease.

TABLE 27

*Insects and Transmitted Diseases of Sanitation Interest in the United States*

| Insect | Disease Transmitted |
|---|---|
| Mosquitoes | Malaria, dengue, yellow fever, encephalitis. |
| Lice | Epidemic typhus, relapsing fever. |
| Ticks and mites | Tularemia, Rocky Mountain spotted fever, relapsing fever, rickettsial pox. |
| Fleas | Bubonic plague, endemic typhus fever. |
| Biting flies | Tularemia. |
| House flies | Intestinal diseases, by mechanical contamination of food. |
| Roaches | Mechanical transfer of enteric diseases. |
| Bedbugs | Relapsing fever (?). |

The discussion of the control of insects is on a general basis and is not related to specific diseases unless definitely noted. Furthermore the use of the term "insect" will be that of general conversation and not of technical entomology. It is recognized that the inclusive term "arthropod" should be used but insect is preferable for easier reading.

## Plague

*Pasteurella pestis,* the causative bacterium of plague, is transmitted from rodent to man or to other rodents by the bite of infected fleas, the most important of which is the rat flea, *Xenopsylla cheopis.* Rats are the most common host for these fleas although ground squirrels, pack rats, and harvest mice have also become infected.

The fleas become infected by sucking blood from rodents or humans sick with the disease. They are capable of transmitting the organisms to

man immediately after becoming infected and they remain infectious for about 20 days. Fleas serve as a mechanical link in the chain of infection —there is no stage of development of *P. pestis* that must be spent in the insect.

Plague is world wide[46] but is most prevalent in India. Known as the "Black Death" it swept through Europe in the 14th century killing about 25 million people. Epidemics of magnitude also appeared during the 16th, 17th and 18th centuries. It has been endemic in China and India since the 19th century. In 1892 an epidemic began in China, spread through the Orient, and before subsiding, was responsible for outbreaks throughout the world.

The disease is an ever present menace and since it is transmitted by the rat flea, it follows trade shipping routes. Inspection of ships for rat infestation, and fumigation if necessary, is routinely undertaken by health authorities to prevent the introduction of plague into seaports. Mooring lines to piers are tarred or equipped with metal rat shields not less than 30 inches in diameter to prevent rats from coming ashore or going aboard. Hawse holes must be plugged when boats are moored to piers and gangplanks must be removed at sunset unless actively in use.

## Typhus Fever

There are two forms of typhus fever important in the United States. Both are caused by rickettsia bodies. Epidemic typhus fever is transmitted from man to man by the body louse, *Pediculus humanus.* Murine endemic typhus is carried from rats to man by the flea, commonly, *Xenopsylla cheopis.*

The vectors become infected by sucking blood from humans suffering from the disease. The louse becomes infectious to man in 5 or 6 days after feeding on an infected human. The causative organisms of the epidemic form, *Rickettsia prowazeki moorseri,* are introduced into the bloodstream by crushing the infected louse or by scratching louse feces, into the wound made by the bite, or into other superficial skin abrasions. Epidemic typhus is a disease of poor hygiene—dirty bodies and clothing.

Great epidemics of typhus have occurred in Europe during wars, being severe enough to interfere with military operations. An epidemic in Serbia during World War I, in 1914–15, caused some 150,000 deaths during a 6 months period. In World War II an epidemic threatened Naples and southern Italy during the winter of 1943–44,[41] the disease having been brought in by refugees from the Balkan countries and prisoners of war returned from Tunisia. Epidemic conditions developed in Naples from October to January, with 371 cases reported for the month of December among a civilian population of one million, plus a large number of military personnel. Hy-

gienic conditions of the civilian population were very bad, particularly in the caverns without sanitary facilities used as air raid shelters. The epidemic was broken by dusting all susceptible persons with DDT powder. This control program was instituted in December and was later extended to mass dusting of the entire civilian population. By January 1944 the peak had been passed and by the end of February the epidemic had subsided.

From a sanitation viewpoint the control of this disease centers around the provision of good personal hygiene, elimination of crowding, and prevention of lousiness. Under epidemic conditions the use of lousicides, such as DDT, for the disinfestation of human clothing becomes important.

### Murine (Endemic) Typhus

It has been recognized[10, 30] that murine typhus is endemic in the southeastern portion of the United States, particularly in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North and South Carolina, Tennessee, and Texas, and may become epidemic under favorable conditions. From 1932 to 1945 some 20,000 cases were reported, with a peak of 5,213 in 1944,[18] practically all of them in the southeastern United States. The reported incidence has decreased since 1944 to slightly over 1000 cases in 1948.

While the death rate is low except for adults over 60 years, the illness and convalescent period persists for several weeks, making the disease one of economic importance.

The disease is not a normal infection of man. Rather it is a disease of rats and only incidentally does it spread to man. The causative organisms, *Rickettsia prowazeki moorseri*, are transferred from infected rats to man by a flea, usually the *Xenopsylla cheopis*. The disease is of importance for discussion because its control consists of the elimination of the rat, particularly the common brown and black rats and fleas that may live upon the rat or in close association with it. DDT dusting of rat runs, burrows, and harborages during 1946–47 reduced reported cases of murine typhus approximately 50 percent in the United States.[43]

## MALARIA, DENGUE, AND YELLOW FEVER

The causative agents for dengue and yellow fever are filterable viruses and for malaria a protozoa, *Plasmodium*. There are three species of plasmodia, each of which causes a particular infection of malaria.[42] They are:

*Plasmodium vivax*—Benign tertian malaria—48 hour cycle.

*Plasmodium malariae*—Quartan malaria—72 hour cycle.

*Plasmodium falciparum*—Malignant tertian—24 to 48 hour cycle.

All of these diseases are transmitted to man by the bite of mosquitoes. The common vectors in the United States for malaria are the *Anopheles*; for dengue, the *Aedes egypti*; and for yellow fever, the *Aedes egypti*, also.

The insects become infected by biting persons having the disease. (It is now known that yellow fever is endemic in the monkeys of South America, Central America, and the African jungles.) These diseases can assume epidemic proportions only when there is a basic numerical relationship between the number of cases, the density of infected mosquitoes, and the concentration of susceptible human population. Absence of any one of these factors will break the chain of transmission.

The virus and parasites from infected mosquitoes are injected from their salivary glands into the wound during the act of biting. Yellow fever patients are infectious to mosquitoes for the two days prior to the onset of the fever and for the initial 3 days of the fever, since it is only during this period that the peripheral blood carries the virus. An incubation period of 10 to 21 days is required in the body of the mosquito before the *Aedes* genus will transmit the infection to man. The virus of dengue fever is found in the peripheral blood from a day before the onset of fever to 5 days after the onset. The mosquito becomes infectious 8 to 11 days after biting the infected human.

Both the *Aedes* and *Anopheline* species are infectious for the remainder of their lives, following infection, and are not materially affected by the disease organisms.

### *Malaria*

Malaria patients are infectious as long as the plasmodium sexual forms (gametocytes) are present in the blood in sufficient numbers to infect mosquitoes. The gametocytes from human blood are ingested by the female anopheline and sexual union occurs in the stomach producing a zygote. The zygotes encyst in the stomach where they produce sporozoites which reach the salivary glands and are carried to the human during the act of biting. A period of 10 to 14 days, which may vary up to 21 days for the vivax, is required for the parasites to pass through their life cycle in the mosquito. Persons harboring gametocytes in the blood become infectious to mosquitoes even though not demonstrating the clinical symptoms of the disease. Indigenous populations in malarious regions develop a certain immunity to the local plasmodium through continuous infection but new arrivals in the area are susceptible.

Malaria is prevalent throughout the world, averaging 304 million cases each year. Prior to World War II, India averaged 150 million cases and 2 million deaths yearly. The *Anopheles gambiae* is an important vector in Africa. Accidentally introduced into Brazil in 1930 this species caused the death of 14,000 persons in one year. The epidemic was controlled and by 1940 the vector was eliminated from that country at a cost of 2.5 million dollars.[13]

Malaria in the United States at one time was a disease of great importance, both for the number of deaths caused and for the economic importance of the money spent in medication and the reduced earning power of infected persons. At one time, the incidence rate of the disease for one year was estimated at about 1,000,000 with deaths put at 5,000. (Accurate information is not available because of the poor reporting of the disease.) The economic cost due to lost income has been put at $500,000,000 per year.

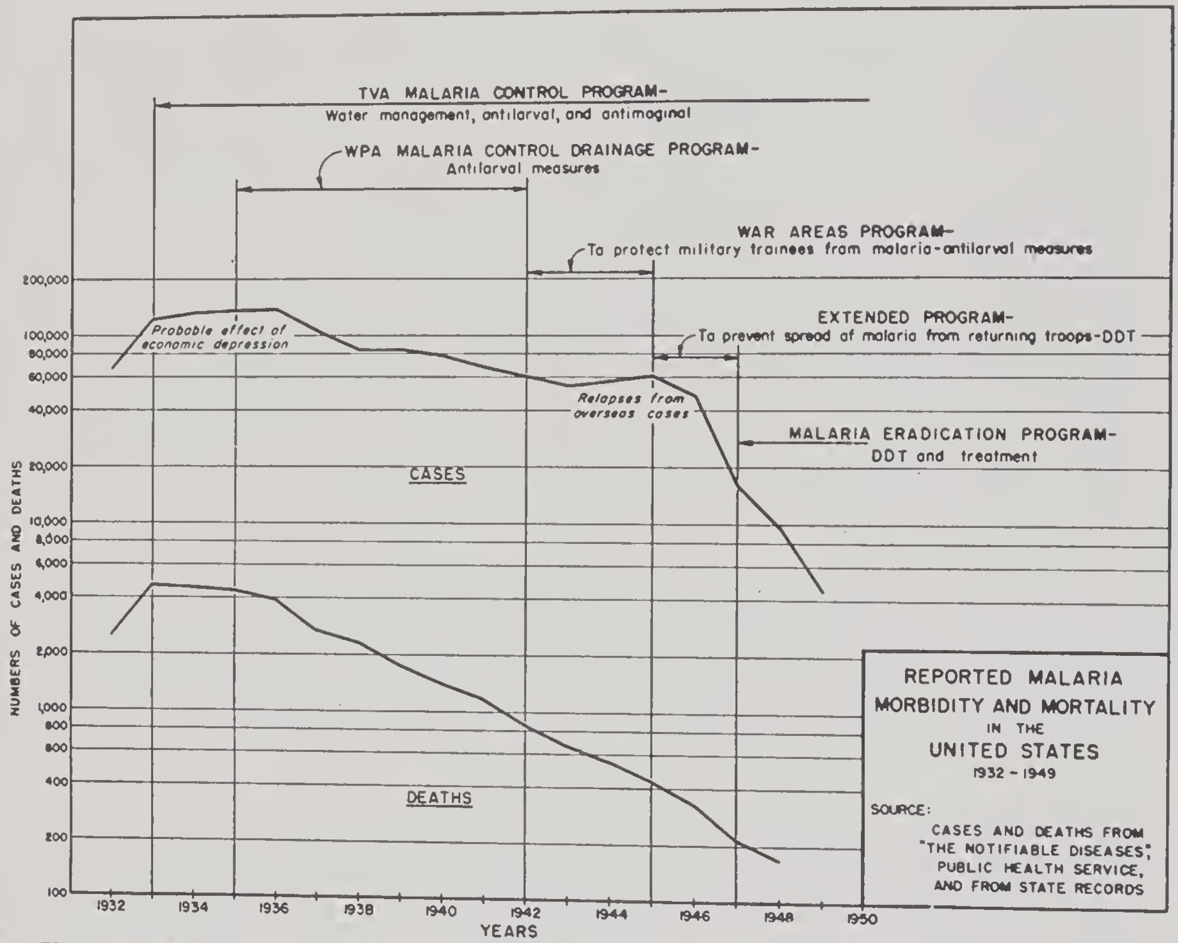


FIG. 97. Malaria Morbidity and Mortality curves. (Courtesy, Justin M. Andrews, United States Public Health Service.)

The combination of apparent natural changes in the incidence of the disease plus the effective control measures instituted by man have practically eliminated malaria from the United States. Figure 97 shows the decrease of malaria morbidity and mortality in this country. As a sanitation activity this has meant the elimination of the mosquito vector and protection of humans from the bite of possibly infected mosquitoes.

## *Dengue*

Dengue is found in tropical regions and becomes prevalent in districts where mosquitoes can breed close to human habitation, in rain barrels and stagnant pools.

A dengue epidemic was reported in Hawaii in 1903 with 30,000 cases and again in 1912 there was another of considerable magnitude. Epidemics were reported in Texas in 1922 with estimated cases between 500,000 and 600,000,[17] and in Florida in 1930. It again became prevalent in Hawaii in 1943 starting with 2 cases in July and reaching 169 cases per week by November.[39] This outbreak was controlled by a vigorous larvicidal program.

### *Yellow Fever*

Yellow fever is endemic in certain sections of South America and West Africa but since *Aedes egypti* is known to breed between latitude 38°N and 38°S it can be prevalent theoretically in a much larger geographical area. The insect vector prefers environments close to human habitation, causing the disease to be one of thickly settled communities.

Yellow fever has been the dread disease of the American continents. Endemic in the tropics it frequently invaded the temperate zone of the United States. During the epidemic of 1878 over 13,000 people died in the Mississippi Valley and the scourge spread to northern cities including New York, N. Y., and Boston, Mass. In past years, New Orleans, La., Memphis, Tenn., Mobile, Ala., Savannah, Ga., and Charleston, S. C. have reported frequent outbreaks.

Havana, Cuba was a center of this disease for over 200 years and with the occupation of the city by the United States forces in 1898 the opportunity to determine the cause and propagation of the disease was made possible. The early investigations of Dr. Carlos Finlay served as the background for the work of Major Walter Reed, head of the Army Yellow Fever Commission in 1900. Reed and other Commission members, Carroll, Lazear, and Agramonte proved that the bite of an infected mosquito was the method of transmission from man to man.[22] Acting upon this conclusion Gorgas, as sanitary officer of the city, proceeded to take measures for the elimination of the insect. This work was instituted in February 1901 and by September of that year the disease was under control. The case rate dropped from 909 per 1000 in 1899 to only 19 in 1908. From this experience Gorgas[16] developed the sanitary control of the Panama Canal in 1904, which made possible the building of this great water way. Without adequate environmental hygiene the canal project would have failed, as had previous attempts. The Canal stands not only as an immense engineering feat, but as a sanitary accomplishment of great magnitude.

Control measures both for dengue and for yellow fever are based on the destructive of the larvae in breeding areas and adults in resting places by the use of insecticides, drainage, and filling of swamp lands. Control is directed only at those species known to be implicated in the spread of the diseases. This is called "species sanitation."

Protection of humans against the bite of the infected mosquito, by the use of screening has also contributed to successful control.

## Rocky Mountain Spotted Fever

Rocky Mountain spotted fever is an infection of *Rickettsia rickettsia.* The disease is transmitted to man by the bite of ticks, *Dermacentor andersoni* in the northeast United States and by *variabilis* in the east and southern United States; *Amblyomma americanum* the Lone Star tick, may be involved in the southwestern part of the country. Wild rabbits, squirrels, and similar animals are the reservoir of infection. Infection is passed from the female tick to her progeny. The vector, other than in congenitally acquired infection, becomes infected by sucking blood from the host. Ticks are infectious for life. Human infections are caused by tick bites with the rickettsia being introduced into the human blood stream during the act of biting. Not all ticks in an area are infected and transmission from an infected tick to a human requires 3 to 5 hours of contact while feeding. There is therefore usually an opportunity to remove ticks from the body before infection occurs.

The incidence of Rocky Mountain spotted fever is not great. However, it has spread throughout the United States and has drawn attention to its presence by the high mortality rate.

Control measures of a sanitary nature are based upon reduction of infected ticks in localized areas below a density that provides a probability of infection. Secondary protection is given by the prompt removal of all ticks from the clothing or body and the use of protective covering.

## Tularemia

Tularemia is caused by the organism, *Pasteurella tularensis*. Human infection occurs in various ways, including transmission by the deer fly (*Chrysops discalis*) and ticks (*Dermacentor andersoni* and *variabilis*). Infection also occurs by inoculation of the skin through handling infected animals such as wild rabbits, hares, woodchucks, muskrats, opossum, quail, cats, deer, dogs and sage hens. Transmission through infected water is not uncommon. Mosquitoes and fleas have been shown to be suitable vectors. Deer flies may remain infective for about 14 days but ticks remain infective for life and may pass the infection on to their progeny.

The disease is prevalent throughout the United States. The incidence is particularly high during the hunting seasons, probably because of the increased contact with rabbits. Protection against infection consists of care in handling any animal or bird that might carry the infection. Use of rubber gloves during skinning operations is an example.

The disease does not present a major problem in the sanitation program.

However, since insects may be involved in the transmission from animals to man, control measures directed toward other diseases, i.e., Rocky Mountain fever, might be elaborated to include some action toward tularemia vectors.

## Relapsing Fever

Two forms of relapsing fever occur. The first, caused by the spirochete *Borrelia recurrentis*, is transmitted from man to man by the body louse. The other type is spread by ticks and the causative agent is another spirochete, *Borrelia duttoni*. The former is closely related to louse-borne typhus in the methods of transmission and of control. The latter is similar to Rocky Mountain fever. Neither form occurs frequently in the United States.

## DDT and the Newer Insecticides

The value of DDT and the other recently developed insecticides is great in the control of insects. DDT and the other new organic insecticides have revolutionized the control methods applied against many insects. Among these new insecticides are: DDT, chlordane, DDD, benzene hexachloride, chlorinated camphene, lindane, and methoychlor.[1]

DDT, dichloro-diphenyl-trichloroethane, was first synthesized in 1874 by Othman Ziedler[44] at Strasbourg, Germany, but its insecticidal properties were not discovered until 1939 when Paul Muller[26] of the Geigy Company in Switzerland began commercial use of the material to control potato beetles.

The compound is a white powder practically insoluble in water but soluble in common organic solvents. It is obtainable in many forms including:

- a 10 percent dusting powder diluted with talc or pyrophyllite.
- a 5 percent residual spray dissolved in deobase kerosene with or without added solvent.
- a 1 percent contact spray with 0.2 percent pyrethrins dissolved in deobase kerosene with or without added solvent.
- a 6 percent delousing spray with 68 percent benzyl benzoate, 12 percent benzocaine and 14 percent wetting agent.
- a 25 percent emulsion containing 10 percent triton x-100 as an emulsifier dissolved in xylene with final DDT concentration diluted to 1 or 5 percent at time of use.
- a 3 percent aerosol containing 0.4 percent pyrethrums, 5 percent cyclohexanone, 5 percent deobase kerosene and 85 percent freon (dichlorodifluoro-methane) as the propellant.

DDT is both a contact and stomach insect poison causing hyperactivity and tremors, followed by paralysis of the locomotor appendages and death.

It is not a repellent or instantaneous poison but its principal value is the prolonged insecticidal effect lasting months after crystals have been deposited on surfaces. Absorption of DDT is by contact, and death occurs after a period of time varying from 20 minutes to several hours. DDT is not an effective agent against all insects, but it is potent against many common ones that are vectors of disease or bring discomfort to people.[3]

DDT is inherently toxic to humans when improperly handled. Oil solutions have caused dermatitis and when accidentally ingested have caused death[38] although the pathological findings were indicative of poisoning by the oil diluent rather than by DDT. To avoid dermatitis when using oil or organic solvent solutions contact must not be prolonged and, should the liquid be spilled upon the skin, it must be removed promptly by washing with soap and water. Contamination of food with the powder must be avoided since ingestion of appreciable quantities will have deleterious reactions.

Most of the other new insecticides are toxic to man although usually so only in large quantities. The effects of several have been tried on rats with the following results showing the dosage required to kill 50 percent of the test animals:[47]

*A Comparison of the Acute Oral Toxicity for Rats of the Newer Insecticides with DDT*

| Insecticide | Lethal Dose 50 mg./kg. body weight | Ratio to DDT |
|---|---|---|
| Beta Isomer, Benzene Hexachloride | 6,000 | 1/24 |
| DDD | 25,000 | 1/10 |
| Delta Isomer, Benzene Hexachloride | 1,000 | 1/4 |
| Alpha Isomer, Benzene Hexachloride | 500 | 1/2 |
| Chlordane | 500 | 1/2 |
| DDT | 250 | 1 |
| Gamma Isomer, Benzene Hexachloride | 125 | 2 |

The toxicity of these insecticides varies for different and even for the same species of animal. The same phenomenon is observed with regard to the effectiveness against insects.

### *Methods of Application*

The dust can be applied with shaker cans, plunger or bellows dusters, rotary hand or power dusters and by airplane.

Solutions or water emulsions are applied with hand, knapsack, or power sprayers and by airplane. A semi-fine spray should be applied for residual effect on walls, doors, screens, etc. This is a spray that will wet the surface without fogging the air and without applying such quantities of solution as to cause it to run off. The nozzle of the sprayer should be held 4–8 inches from the object being treated. Screens may also be treated by applying with a cloth dauber.

A solution or water emulsion may be applied to the exterior of buildings with standard large type sprayers or with power units. They should produce a fine mist that will drift readily with a light breeze. Airplane spraying equipment must produce a similar mist. To acquire adequate distribution, DDT concentrations are reduced for this work to 1 percent. Aersol bombs are used directly from the container.

## House Flies

The common house fly, *Musca domestica*, has been suspected of playing an active part in the spread of intestinal diseases. Its habits are such that this suspicion seems to be justified. Fly eggs are deposited and hatched in decaying filth. Flies feed on similar material with human wastes serving as a favorite item of food. There are many opportunities for infection.

The feeding habits and the anatomy of flies favor transmission of contaminated material. The house fly does not bite but sucks up its food in a liquid state. When confronted with solid food it spits out saliva to make a solution of the desired food. This makes an excellent opportunity for spreading infected material. The fly, like most insects, defecates copiously while eating. This habit is another avenue for the transmission of infection. Finally the body of the fly is covered with many fine hairs ideally suited for carrying filth from one place to another.

Incidence of fly-borne disease cannot be expressed in figures for none are available. However, studies conducted at Hidalgo, Texas, have shown the direct relationship between fly incidence and the incidence of diarrheal diseases. The relationship of house flies to the transmission of cholera is considered important in the control of that disease. Experimental work has shown the possibility of the house fly's transmitting the eggs of parasitic worms to the food of man.[17] The role flies may play in the transmission of poliomyelitis has not been established but neither has it been eliminated as a factor. In general terms, the incidence of house flies is accepted as a measurement of the sanitary conditions of an environment.

The following control measures refer particularly to the common house fly although they are generally effective against other types of flies, such as the blow flies, that may create health hazards by the mechanical transfer of infectious material.

Introduction of some of the newer insecticides has diverted attention from some fundamental methods that must be applied in any fly control program. It is an easy matter to spray the interiors of restaurants, barns, and other food handling areas, and it is good publicity to permeate an entire community with a fog of DDT or other insecticide. Taken alone, these methods are insufficient. Effective control of flies requires effective preven-

tion of breeding. Other methods should be considered auxiliary approaches, applicable in certain places or under certain circumstances.

Flies breed, i.e., lay their eggs, in moist, warm accumulations high in organic matter. Horse manure is the chief breeding material if it is available. Other manure also serves if horse manure is not convenient. Decaying garbage or foods are other popular breeding places. Moisture is required for the larvae that hatch from the eggs, because they do not chew but must obtain their food in a liquid state. The larvae develop into pupae which in turn hatch out into the adult fly. In warm weather the complete cycle of egg to adult fly may take place in about 10 days. Cool weather or poor food supply available to the larvae will extend this period. The fly prefers light to darkness and is attracted to food by its sense of smell.

The surest method of control of flies is the elimination of breeding places. Complete screening of buildings is also of vital importance. Screen doors should open outward to be effective.[7, 8] With use of the new insecticides fly traps are unnecessary at food preparation establishments. The following program has been found effective in controlling the numbers of flies in any community:[6]

1. Improvement of sanitation practices in general.
2. Screening of homes and food preparing and handling places.
3. Application of residual sprays to selected fly resting places.
4. Application of larvicides in selected sites.
5. Broadcasting of space sprays over extensive areas.

An application of a residual spray containing DDT, chlordane, lindane, or methoxychlor should be made to places indoors or outdoors where large numbers of flies congregate.[27] The spray should be applied to surfaces where numerous fly specks appear, especially on window and door screens, rafters, ledges, light cords, and lamps. The spraying of barns and outbuildings has successfully controlled flies on the farm. Milk containing more than 1 ppm. of DDT has been banned from interstate shipment. Since DDT on the body of milch cows or consumed on feed will concentrate in the fatty tissues of the milk and so appear in a concentrated amount in the milk other insecticides have been substituted for DDT around cattle or dairy barns and milk houses.

DDT is safe to use in food production plants such as slaughter houses, packing plants, and markets, if proper precautions are taken to prevent exposure of food to the spray.[2, 35, 36] Prior to spraying in food preparation and serving establishments, all food, utensils, and preparation tables, must be covered.

The exterior of garbage cans and adjacent areas should be sprayed to kill adult flies, since the flies rest in these locations when seeking food.

Interiors of privy houses and the ground close to manure piles should be treated since flies also rest in these places, after feeding.

Application of a 5 percent DDT residual spray should be made at the rate of 1 quart per 250 square feet of surface. The surface should be wetted without runoff, as in applications for bedbugs.

Strains of flies resistant to DDT have appeared in several sections of the United States, making the use of some other insecticide necessary. They

FIG. 98. Garbage can spraying with DDT for fly control. (Courtesy, United States Public Health Service.)

are used when DDT begins to show a loss of effectiveness. Chlordane and methoxychlor are good substitutes. Methoxychlor has been accepted as a substitute for DDT around dairies. However, neither of these chemicals gives the lasting effect of DDT.

The results of spraying programs carried on in various parts of the country have shown that it is not necessary to spray the interiors of rooms in houses having screened windows and doors. Where screens are used good results have resulted from spraying only the doors and the area around them.

Larvicides, preferably chlordane, if DDT resistant flies are present, should be used for the treatment of fly-breeding places such as manure

piles, pit privies, and compost piles. Chlordane appears to be the larvicide of choice in most instances and is applied as an emulsion of 2 to 4 percent content at the rate of 50 to 100 mg. of chemical per square foot of surface. This gives protection for 8 to 11 weeks. Garbage cans should be treated in the same manner.

Space or area spraying has been used in some communities to eradicate flies in areas around buildings. The insecticide is dispersed as a mist or fog by means of especially designed blowers. Regardless of the type of dis-

FIG. 99. DDT power spraying for fly control. (Courtesy, United States Public Health Service.)

penser, the goal in treatment is to kill that portion of the fly population that escapes the effects of residual or larvicidal control efforts. The results obtained are spectacular, temporary, and of doubtful economic justification. Around poorly maintained dumps, daily spraying may be necessary to produce good results. On the other hand, in an area where sanitation is good and extreme fly-breeding conditions do not exist, space spraying may be sufficient for outdoor control if applied once every two or three weeks.

Emulsions or solutions containing 5 percent DDT are the most commonly used insecticides in space spraying. The rate of application is about 0.4 pounds of DDT per acre, or, roughly 1 gallon of the 5 percent solution per acre. The effective range of most machines while in motion is about 200 to 300 feet. Choice of the proper size of droplet is important since over-

sized particles will settle out too rapidly but undersized droplets will drift and shift with slight air currents making control of application difficult.

Space sprays may be applied by aircraft. The rate of dosage remains the same, i.e., 0.4 pounds of DDT per acre, but it is sometimes found advantageous to use a 20 to 30 percent solution to reduce the weight of the load of DDT to be carried. Obviously, there are hazards associated with the low-level flying necessary when aircraft application of sprays is utilized. Usually, as effective methods can be found without the added dangers in the use of aircraft.[6]

## Cockroaches

The cockroach, *Blatella germanica*, (the German roach or Croton bug), *Blatella orientatis*, (oriental cockroach), and the *Periplaneta americana* (American cockroach) is an ubiquitous insect found in all parts of the tropical and temperate zones. In the United States, the German roach is the most prevalent.

None of these insects has been implicated directly with disease transmission. They do like human food and are usually to be found in kitchens and other places where food is prepared or stored. They seem to present a hazard as mechanical transmitters of disease organisms. Experimental work has shown the ability of the cholera vibrios when ingested by cockroaches to pass through the intestinal tract of the roach and appear as viable organisms in the dejecta of the insects.

The secretions of cockroaches impart an unpleasant characteristic odor to food, often rendering it unusable with consequent economic loss.

The domestic roach hides in cracks, crevices, and in dark places behind or under objects, particularly where there is warmth. Walls close to stoves and behind sinks are favorite breeding places. The insects are nocturnal and so their presence may be missed until the prevalence becomes high or until they are inadvertently discovered. They eat almost everything although starch and sugar are preferred. Metamorphosis is incomplete; the young that hatch from the eggs resemble the adults except in size and color. The eggs are arranged in a capsule which the female frequently carries partly protruding from the abdomen until shortly before the eggs hatch. Cockroaches may be found almost anywhere food is prepared, handled, or stored.

The best control is scrupulous cleanliness, disposal of waste scraps, and storage of food in tight containers. Pyrethrum, DDT, sodium flouride, and chlordane, particularly the latter, are effective insecticides. It is practical to spray with DDT for flies, ants, and roaches, in one operation by covering all cracks and surfaces known to be breeding places of the insects.

The best procedure is the treatment of all cracked surfaces with the insecticide spray. Stoves, tables, chairs, refrigerators, cupboards, shelves, sink drainers, and broken sections in walls or ceilings together with base-

boards should be covered. Following the spray treatment, all hiding places should be dusted with a 10 percent powder. The powder must be placed in the crevices. One application gives satisfactory control for about 6 months even though reinfestation may occur through infested supplies and other materials brought into the building or room.

Sodium fluoride dust, when placed in cracks and crevices, is as effective for roach control as DDT. However, it is lethal to man and therefore more dangerous to use around food. For this reason DDT or chlordane is preferred in food handling establishments.

Chlordane, dissolved in deobase kerosene or other organic solvent, is a very effective spray against roaches. It has been shown to be superior to DDT and has replaced it for roach control in many instances.[24] It is known to be more toxic than DDT and should be used with care.

### Bedbugs

Like the cockroach, the bedbug (the common bedbug *Cimex lectularius*) has not been incriminated definitely as the vector of any disease. Its life habits are such that strong suspicion is directed toward it in the spread of any diseases, the causative organisms of which are carried in the human blood stream, and are known to be spread by mechanical transfer.

Bedbugs feed on warm-blooded animals and birds. They are important to man because they so frequently live in close association with him. Bedbugs are nocturnal and their presence is often undetected until the effects of their bites are noticed. They are well adjusted to man's habits and are objectionable for esthetic reasons.

Normally these insects hide in cracks and crevices in walls, floors and furniture. Eggs are laid in the normal daytime hiding places. Bedbugs go through an incomplete metamorphosis, i.e. the eggs hatch into immature models of the adults and are hungry at birth. The adult can live for weeks without food but is sensitive to temperature; many are killed by a temperature of 100° F. with high humidities and become inactive at 60° F.[17]

The advantage of DDT for bedbug control has been amply demonstrated and is now widely used. It has replaced cyanides or methyl bromide fumigation. One treatment with a residual spray placed on mattresses and bedsteads is effective for at least a year.[27, 28] The spraying of theater seats, railway coaches, cabins, and busses has eliminated infestations among the general public.

The spray is deposited on the under side of bed rails, in cracks and crevices, in the joints, and on the springs. Sides and ends of mattresses and pillows are slightly moistened. It is not necessary to cover the entire surface. Beds may be occupied 3 hours after treatment.

In open barracks the walls should be treated to a height of 5 feet above

the floor, particular care being given to cover cracks and crevices. In plastered rooms, cracks adjacent to the baseboards should be covered and if the wallpaper is loose the area behind it should be sprayed. Smooth surfaces do not retain the crystals as readily as rough ones and therefore must be treated more frequently.[14]

When properly applied 1 quart of spray will cover 250 square feet of surface. DDT impregnated resins for painting are on the market as a replacement for spraying. They are effective in killing power and retain their toxicity for considerable periods. Water emulsions may be substituted for oil spray when surface staining is not objectionable.

Since bedbugs feed only once between moltings, remaining hidden in remote crevices otherwise, at least a week is required for complete eradication. Marked reduction in prevalence and cessation of annoyance occurs within 24 hours.

Other methods of control were used before the introduction of DDT. Although DDT has provided a method simpler and surer than the previously used ways, control can be obtained without the use of DDT. Cleanliness is essential and its value should not be minimized even with the use of DDT. Keeping woodwork and floors painted, then filling the cracks in which bedbugs may hide and breed, will help materially. If iron bedsteads are used heat can be used to good effect to kill any form of the insect that may be present in springs, crevices, or any other part of the bed. Kerosene can be applied to floors, furniture, and crevices in walls as an effective insecticide. Needless to say, suitable precautions should be used against the possibility of fire. Addition of pyrethrum to the kerosene increases the effectiveness. The use of hydrocyanic gas and methyl bromide gas for general fumigation has been mentioned. These gases are equally effective in the eradication of the human population, so fumigation should be done only under the direction of well-qualified pest control operators. Many cities prohibit use of hydrocyanic gas or methyl bromide gas by other than licensed fumigators.

## Fleas

There are many species of fleas but the ones of importance are those that may infest domestic animals, particularly the dog and cat fleas (*Ctenocephalides felis* and *canis*) and the oriental flea (*Xenopsylla cheopis*). The former may become established in the home and develop into a first-rate pest while the latter is the principal vector of plague and endemic typhus.

Fleas pass through a complete metamorphosis—egg, larva, pupa, and adult. The eggs are laid on the normal host—the dog, cat, rat, or other animal—but they frequently become dislodged and deposited in the areas frequented by the host. Thus, the eggs of the domestic cat or dog flea may

be found in the cracks of floors and the rugs of rooms in the home. It is there they hatch and find food from the minute particles of organic matter present. The eggs of the rat flea hatch in rat runs and nests, the larvae develop and the pupae pass into the adult flea form.

Normally the flea remains on its usual host. However, the newly formed adult insect will attach itself to other warm-blooded animals if the usual host is not present. The rat flea seldom leaves the rat unless it needs a better food supply. Infected rats may die from the disease or for some other reason, whereupon the fleas that have been living on the rat look for a new host. If a human is conveniently near, the fleas may migrate to him.

Dusting household pets and their beds with DDT powder will kill the fleas present. Infestation of humans may also be eliminated by dusting. Oil solutions of DDT should not be applied to animals since the oil burns the skin and sufficient DDT may be absorbed through the skin to produce sickness. A 10 percent powder can be used on dogs or humans. Since cats lick themselves a powder containing no more than 5 percent should be used on them. If homes become infested, care should be exercised in disinfesting any areas used by domestic pets. Floors should be scrubbed to destroy any eggs, larvae, or pupae present and to remove organic matter that may serve as food for the larvae. Kerosene with DDT or pyrethrum painted into the cracks and crevices kills all forms of the insect. Farm outbuildings and yards can be rid of fleas by spraying with DDT solution or emulsion at a rate of 1 quart of a 5 percent solution per 500 square feet.[37]

Dusting rat burrows with 10 percent DDT powder will eradicate the flea population from the rodents and will give a practical method for reducing the spread of endemic typhus fever.[7, 18] Such dusting should always be done before any extensive rodent eradication, particularly if endemic typhus fever is prevalent. The DDT should be applied several days before the eradication of rats actually starts, so that the rats will have a chance to carry the powder through their runs and nests to the fleas. Indications are that the amount of DDT picked up by the rat is not sufficient to kill him, so that rats and fleas cannot be eliminated in one operation.

## Lice

The species of lice important in the transmission of diseases to man are the head and body louse, *Pediculus humanus capitus* and *corporis*. The crab louse, *Phthirus pubis*, although a filthy insect and an extreme nuisance, is not considered implicated in the transmission of insect-borne disease. The head and body louse are the vectors for the spread of epidemic typhus and relapsing fever.

Lice breed in the hair or clothing close to the body. Eggs are cemented to the hair and are known as "nits." They hatch out into miniatures of the

adult louse and immediately commence to feed. They pass to the adult stage through several molts; it takes about 16 days for eggs to develop into mature forms. Lice are prodigious eaters. Having become infected with typhus or relapsing disease, they become a hazard to other humans because of the disease causative organisms in their body fluids and in their feces. Human infection occurs when the infected feces or crushed bodies are rubbed into abrasions in the skin. Lousiness and poor personal hygiene generally go hand in hand.

Typhus and relapsing fever are dreaded diseases of military populations. Special methods have been developed for the disinfestation of clothing and bedding. Efforts are directed at developing the best personal hygiene possible. Good personal hygiene must be made possible by the provision of bathing facilities, soap, and hot water. Some method should be available for the disinfestation of clothing while the owners of the clothing are bathing. Heat, if dry, at 140° F. kills both the developed insect and the nits. Steam sterilization kills all forms of the insect and also sterilizes the clothes. Dry heat should be used for such articles as leather, rubber, felt, or any other items that would be adversely affected by the dampness.

DDT has replaced all other methods of disinfestation where the chemical is available. It can be used by individual application of dust from small shaker cans or it can be dusted *en masse* with hand or power dusters. The DDT in the clothing affords lasting protection unless the clothing is washed frequently.

The procedure for mass dusting is as follows:

Collars, belts and other constrictive clothing are loosened to permit dust to pass between layers of clothing and against the body. The head is dusted until the hair appears white after which the nozzle of the duster is placed in each sleeve next to the skin and powder blown into the sleeves and up to the armpits. Dusting is continued until the powder emerges from the loosened collar. The face is turned away from the dust to avoid inhalation. The front and back of the body is dusted by inserting the nozzle in the neck band, alternately front and back, and directing the powder downward over the body surface. A similar dusting is given the lower portion of the body from the waist band.

Dusting DDT powder from a shaker can on the heads of school children has been very effective in eradicating head lice without the need for loss of school time. A dust of 10 percent DDT in talc is used. Since the powder is not an ovicide a second dusting will be required after about 10 days.

The benzyl-benzoate DDT delousing spray is an ovicide as well as an insecticide and is sprayed directly on the previously washed body. Spray is directed to all parts of the body including the head. The eyes are protected by covering them with the index fingers when the eyebrows are

treated. Clothes may be resumed before the liquid dries and bathing must be suspended for 24 hours. The same underclothing should be worn for 3 days to prevent reinfestation. Usually a single treatment removes all lice.

Bedding and clothing may be deloused by dusting but for extensive application, fumigation with methyl bromide is preferable. The fumigating procedure kills lice and eggs after a short exposure. The gas is very penetrating, does not shrink fabrics or leather, and prior sorting of clothes or bedding is not required. The fumigant is toxic but when used by trained personnel can be safely handled without gas masks. Large gas tight steel chambers capable of withstanding pressure are provided. The chambers are filled with the articles to be deloused and methyl bromide is admitted at the rate of 9 pounds per 1000 cubic feet and retained for 30 minutes. Forced circulation is applied to distribute the gas evenly and sufficient pressure is generated to give quick penetration into fabrics. After exposure the chamber is ventilated by exhausting it through suction for 10 minutes. Clothes are then removed, shaken, and aired for 5 minutes.[31]

Ten percent DDT powder can also be used for disinfesting railroad cars, theater seats, and other places of a similar nature.

## Ticks

Ticks, in this country, are of public health interest in restricted areas and in diseases that do not cover wide areas. However, where tick-borne diseases are prevalent, protection against the bites of ticks becomes important.

Actually, the life cycle and nature of ticks is such that there is little that can be done of a practical nature to rid the vast land expanses of ticks. Ticks are "wild" insects and they do not become pests in the home except under unusual circumstances. Many species of ticks exist, but the wood tick, *Dermacentor andersoni*, and the dog tick, *Dermacentor variabilis*, are the vectors of chief importance in this country.

Eggs of the tick are laid on the ground in vegetation and it is here that they hatch into small replicas of the adult except that the adult has 8 legs and the newly hatched form has only 6. The young insect soon attaches itself to a warm-blooded animal where it takes its first meal. Successive molts are interspersed with blood meals until the adult tick emerges. The life cycle takes about a year for completion.

Despite the extended life cycle of the tick, it has at least two other characteristics that make it a formidable enemy. It can go for longer than a year without food and it passes the disease organisms, in Rocky Mountain spotted fever and relapsing fever, on to its progeny. This produces crops of infected insects that have never fed on an infected animal.

Tick-borne diseases are particularly prevalent among people working or traveling through undeveloped, wild country. Some danger is attached

to the introduction of infected ticks into the household through domestic animals. Disease preventive methods are directed toward these possibilities.

Persons passing through or working in tick infested localities should remove all ticks from the body at frequent intervals. Ticks even when feeding must remain on a person for about 4 hours before transmitting infections; prompt removal is therefore the best prophylaxis. A good routine is to strip at noon and at the end of the day so that ticks can be detected and removed. Repellents are of little value against ticks,[5] and DDT has little if any effect. Preventive inoculations should be given to persons working for an *extended* period of time in a known tick-infested area. Grossly infested areas should be burned over or the vegetation should be clipped to the ground.

In localities where ticks are prevalent, pets, particularly cats and dogs, should be routinely freed from the insects by mechanical removal. The ticks must be removed carefully so that they will not be crushed; it is important to avoid infection from fluids in the insect's body.

### Use of Repellents

Chiggers and other mites are effectively repelled by the use of dimethyl phthalate, indolone, and Rutgers 612 or admixtures thereof. When rubbed on the skin these repellents are effective for about 3 hours. Liquid soap dispensers are a convenient method for individual distribution where a large number of people are involved.

Repellents should be applied to trouser bottoms, socks, and rubbed on the legs above the ankles and arms above the wrist. If outdoor sleeping is practiced, additional coverage should be given at the waist and neck.

Under exceptional conditions, clothing may be impregnated with repellents remaining effective for about a month even if laundered several times.

### Mosquito Control

The three most important mosquito genera are the *Anopheles,* transmitting malaria; the *Aedes* transmitting dengue and yellow fever; and the *Culex* transmitting filariasis. Only certain species in each genus are involved in disease transmission. In addition other species in these and other genera are annoying pests in localities where they are not considered disease vectors. *Aedes egypti, Anopheles maculipennis* and *quadrimaculatus* and *Culex tarsalis* are of importance in the United States.[23, 25] The *Culex tarsalis* is suspected of transmitting arthropod-borne virus encephalitides. Other mosquitoes that may be involved have not yet been determined.

A knowledge of the life history and characteristics of the mosquito is necessary for understanding the control methods that are undertaken or

for evaluating methods. Fortunately, the life cycle of species in various genera is similar enough to permit a general outline with exceptions noted.

## *Life History*

Although the adult insect is free flying, mosquito eggs, larvae, and pupae require water for existence and further development. Egg laying characteristics differentiate to a certain extent between genera. Anopheles eggs are deposited singly on water surfaces in batches of 100 or more; they are boat shaped, with a membrane or float on each side. Aedes eggs are deposited singly on the sides of the water containers just above the water level. Batches of 50 or more are deposited at one time. Culex eggs are deposited on water surfaces in boat-shaped masses containing several hundred eggs cemented together.

Under favorable conditions of which temperature is the most important, the eggs hatch out in about 12 to 72 hours into the larval stage of the insect. Larvae are active, cylindrical organisms that develop by molting in four different stages called instars. First instar larvae, just after hatching are minute and transparent. After 24 hours the first molt occurs and the second instars emerge. These are darker and larger and are readily noted in clear water. The third and fourth instars appear in a few days and then the pupal stage develops. Larvae are active feeders in all stages. They may grow to a length of one-half inch before passing into the pupal stage.

Mosquito larvae require oxygen from the air. All genera except the Anopheles have a syphon or breathing tube attached to the posterior portion of the abdomen. The tube of the Culex is long and slender and that of the Aedes short. Larvae attach themselves by the tip of the syphon tube to the surface of the water and hang downward at an angle. In this position they obtain air from the atmosphere and food from the water. Since Anopheles larvae are without syphon tubes they lie parallel to the water surface to obtain air through a flat stigmatic opening in the posterior part of the body. These differences are excellent characteristics by which the genera can be differentiated. Larvae wiggle through the water in search of microorganisms upon which they feed. It is this movement that gives them their common name of "wigglers."

The pupal stage carries two breathing tubes or ear-like trumpets reaching to the water surface. The pupae do not eat but they are motile, moving in a tumbling-like motion from which their name of "tumbler" originates. This stage molts by splitting the body cover and the full grown insect gradually emerges; after resting upon the water surface until the exoskeleton has hardened, it is ready for flight. The time from egg to adult mosquito

varies with temperature, food supply, and other factors but it usually takes from 10 to 20 days.

Male mosquitoes subsist on plant juices but the female is blood sucking, requiring a blood meal before ovipositing occurs. Mosquitoes are more active in warm humid weather. They do not bite at temperatures below 60° F. The time of day when mosquitoes bite varies with the species, some biting in the evening, some in daylight and others at any time.

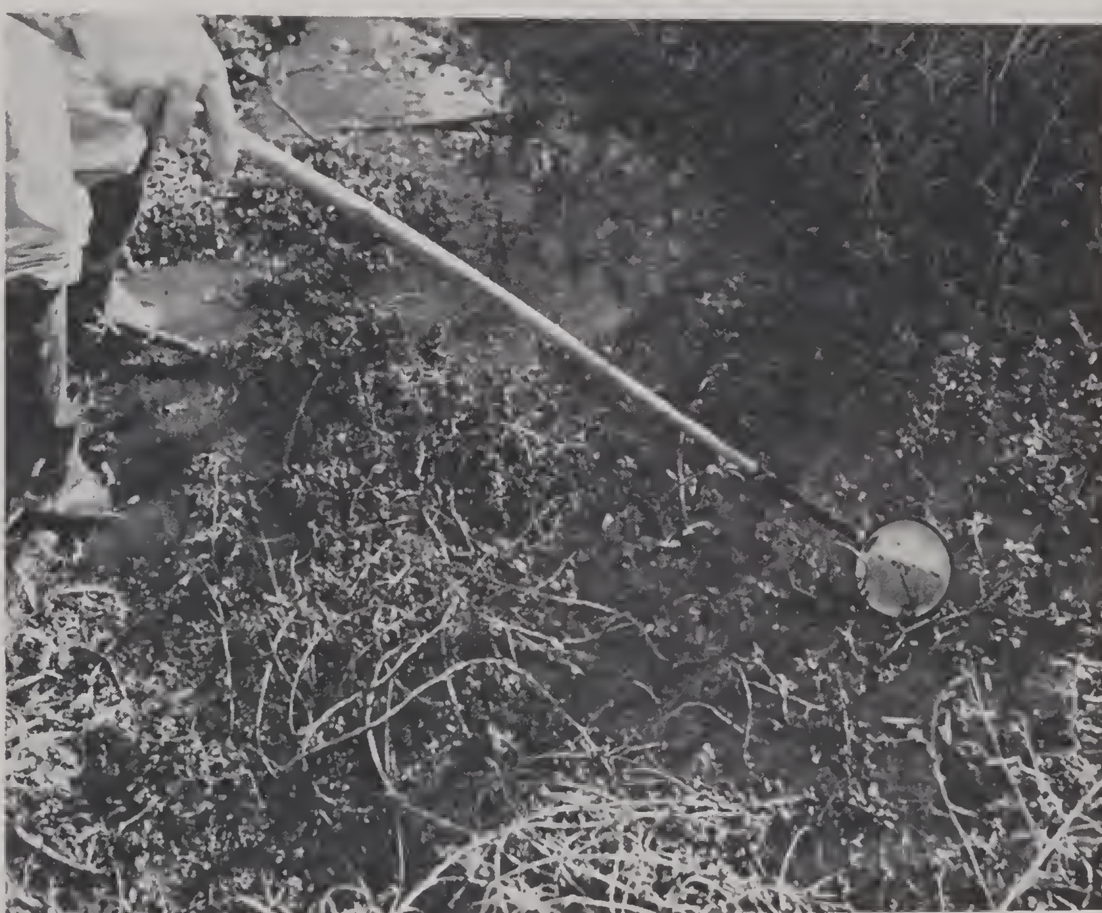

Fig. 100a. Dipping mosquito larvae. (Courtesy, United States Public Health Service.)

Mosquitoes hide in darkened and shady places during the day, under buildings, in crevices, or under leaves. Adult female mosquitoes may live 3 months but the normal life span is about 2 weeks.

### *Identification*

Differentiation of genera and species of mosquitoes is necessary to determine the locations and types of breeding places and to formulate adequate control measures. Only a few different species may be found in a given locality making possible identification of adults by the markings on their bodies and by other morphological characteristics. Generically, larvae can be identified by the position and nature of the breathing syphon, but dif-

ferentiation of species requires considerable knowledge and skill beyond that of the average person involved in field control work.

Characteristics of the adult Anopheles mosquito frequently make it possible to differentiate it in the field from other genera. At rest the position of the body is at an angle to the support. The body, head, thorax, and abdomen, are in a straight line, head downward. The Culex and Aedes genera rest with the abdomen parallel to the surface and with a definite curve in the body at the thorax. Anopheles mosquitoes are usually larger

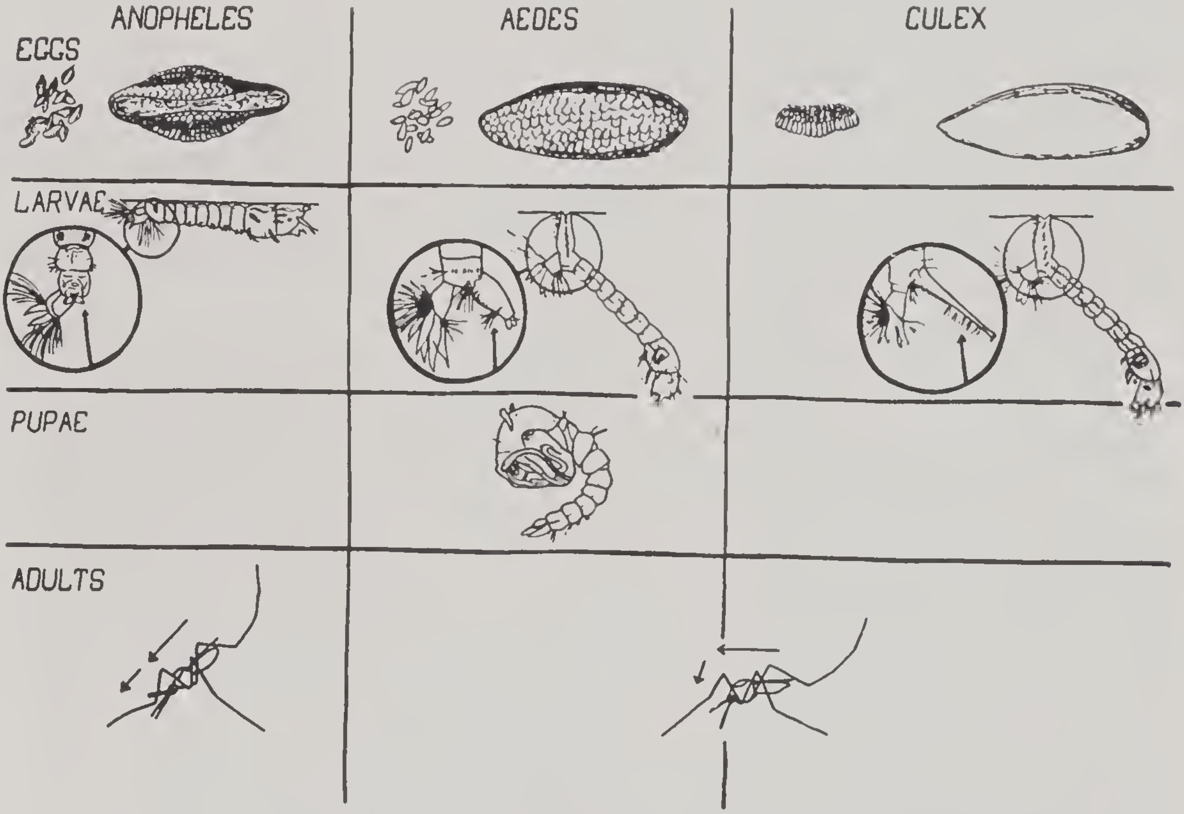


FIG. 100b. Metamorphosis of the mosquito

than the Culex or Aedes and frequently have wing markings. Differences exist in the palpi of the females also.

Various species of adult mosquitoes are identified by markings on the wings and body and by size and color. Detailed descriptions for use in identification may be found in published articles.[33, 34]

The flight range of mosquitoes varies considerably and influences control measures that can and must be taken. The *Anopheles quadrimaculatus* has a range of about 1 mile. This mosquito has been the important malaria vector in the eastern part of the United States. The *Anopheles freeborni* has a seasonal migration range of 10 to 15 miles. *Aedes solicitans*, a pest mosquito, with the aid of a favorable wind has been known to cross a salt water bay 20 miles wide.[12] The range of *Culex pipiens*, another pest mosquito, is about a mile, while the *Aedes egypti*, historically one of the most

important mosquitoes, breeds close to human habitations and seldom flies far from human dwellings.

The breeding habits of mosquitoes are shown in Table 28.

### *Control Methods*

Prevention of insect-borne diseases may not necessarily mean complete programs of vector eradication. With the new insecticides and with decreasing incidences of some diseases, methods other than complete eradication may be cheaper, easier, and as effective. However, mosquitoes have been such important disease vectors, and they still are so important as nuisances, that mosquito eradication is a matter of concern.

Before any control activity can be undertaken the nature of the problem must be understood. Disease incidence reports furnish some help in such a disease as malaria because it is well known that malaria is transmitted by a very few species of Anopheles. There would be no need to attempt Culex or Aedes control to prevent malaria.

When the disease incidence, including geographical and chronological occurrence has been determined the next task is an entomological survey of the community to determine the location and magnitude of breeding areas of those species known to have significance for the disease of interest. Adults are identified from mosquitoes caught in normal resting places during the daytime or from traps set at night to catch the mosquitoes as they forage for food. The day catching is usually done "by hand" with glass tubes into which the resting mosquito can be sucked. The night traps usually consist of a mechanical device including a light, a fan for sucking or blowing the mosquito into a chamber containing an anesthetic, and a second chamber for holding the captured mosquito. Other types of traps commonly used are enclosures baited with a live animal and made in such a way that mosquitoes can enter in their search for food but cannot readily escape.

Samples of larvae and pupae are obtained from the bodies of water in which these forms are developing. Since one of the best places to attack the mosquito life cycle is in the water stages (egg, larval, or pupal) the locations of the breeding places are important. Since various mosquito species have distinct preferences for breeding places and for resting places for adults, the task of obtaining suitable specimens for identification is simplified if there is knowledge of the probable species involved in disease incidence.

Once the details of mosquito species and breeding places have been developed, the next task is to determine the method that will give the most efficient control of the insect. This requires entomological knowledge to evaluate the effectiveness of control measures and engineering training to

prepare and execute the actual control measures. Eradication of the adult mosquito in nature is extremely difficult because of its mobility. The adult

TABLE 28

*Breeding Habits and Biting Characteristics of Common Mosquitoes*

| Genus | Species | Biting Characteristics | Breeding Habits |
|---|---|---|---|
| Aedes | egypti | Early morning—late afternoon | Exclusively in cisterns, rain gutters and other accidental collections of water close to habitations. |
| | taenorhynchus | Day, shady places | Salt marshes when flooded by rain. |
| | triserratus | Daylight | Pools and ponds in wooded areas. |
| | sollicitans | Daylight | Salt marshes. |
| | vexans | Daylight | Rain pools and flood waters. |
| Culex | quinquefasciatus | Night | Water barrels, street gutters, catch basins and ground pools if polluted. |
| | pipiens | Night | Similar to quinquefasciatus. |
| | salinarius | Night | Grassy pools with fresh or brackish water. |
| Anopheles | albimanus | Dusk, night | Pools, swamps, along edges of streams where there is no current, also in artificial containers. |
| | barberi | Night | Tree holes. |
| | bradleyi | Day, night | Brackish water, salt marsh pools. |
| | crucians | Night, day in woods | Fresh water swamps. |
| | maculipennis | Day, night | Small, shallow sunlit pools containing algae. |
| | punctipennis | Night | Margin of flowing streams, clear cool water. |
| | pseudopunctipennis | Night | Open sunlit ponds containing vegetation. |
| | quadrimaculatus | Dawn, dusk, night | Fresh water ponds and swamps containing floating vegetation. |
| | walkeri | Day, night | Fresh water marshes containing vegetation. |

can be eliminated in restricted areas such as homes, theaters, and meeting halls. It is impracticable to try to eradicate mosquitoes from a large area by killing off the adult. The most effective methods are those directed toward the water life stages.

Control of the water stages of mosquito development directs attention to the egg, larval, or pupal phases of life. These forms of the mosquito can be eradicated by eliminating water bodies; by rendering existing bodies unsuitable for breeding either by poisoning the water or by agitating it in such a way that eggs, larvae, or pupae will be killed or deposited on the

FIG. 101. "Light trap" used for mosquito catching. (Courtesy, United States Public Health Service.)

banks of the stream or pond; or by introducing natural enemies, such as fish, into the breeding places. The choice depends upon many interrelated factors.

Since eggs are relatively inert and the pupae do not eat, the larvae is the stage of development most vulnerable to attack. The control methods that are used are:

Elimination of breeding places:

1. Draining swamps, marshes, ponds, etc.

2. Filling.
3. Emptying and destroying artificial containers of water.
4. Training streams and trimming lake or pond banks so that clean edges are produced to eliminate shallow, marshy areas adjacent to the stream or lake that may serve as mosquito breeding areas.
5. Diversion of stream flow to prevent swamp or pond formation.

Treating bodies of water to render them unsuitable for breeding.

1. Use of larvicides.
2. Fluctuating water level so that larvae and pupae are left behind on dry banks or else carried into clear water where natural enemies can get them.
3. Periodic release of water in such velocities that larvae and pupae are drowned in the turbulent water and those left behind are stranded on dry ground.
4. Changing the vegetation surrounding the water bodies to give an environment contrary to that desired by the species to be eliminated.

Introduction of natural enemies.

1. The use of small fish.
2. Encouragement of propagation of certain insects that may feed on mosquitoes, either in the larval or adult stage.

Drainage is considered a permanent type of control. Once the drainage system is installed it removes water before mosquitoes can develop, provided the drainage system has been properly designed and installed and provided it is maintained in such a way that it will do the job for which it was designed and not become a mosquito breeding area itself.

Lined, unlined, or rock filled ditches and in special instances sub-surface drains are used to remove standing water in mosquito control. Drainage ditches must be especially planned and constructed for the purpose. Surveys to develop terrain characteristics and determine the best type and location of the drainage system to be installed are of vital importance to the undertaking. They must be made by well trained, competent personnel fully familiar with these types of problems.

Ditches must be uniformly graded and have a width to depth relationship that will assure a steady flow of water through them. They must flow into natural creeks or other bodies of water and spaced to drain off all water from the land. Marsh land along tidal waters can be drained by construction of a dike, equipped with a tide gate which will permit drainage of the marsh at low tide but prevent back flow into the area on high tide.

It is important that the drainage system carry away all water without leaving stagnant pools. Frequent inspections must be made to correct pot holes and other depressions that may develop in the bottom of unlined

ditches. Bottoms should be narrow and U-shaped, with sloping sides and without sharp bends.

The main (outfall) ditch should be constructed initially and branches (laterals) installed when and where required. Feeder or lateral ditches should join the main ditch at an acute angle to prevent deposition of silt or debris and erosion of the opposite bank at the junction point. Where ditches pass through culverts the grade should be increased to prevent

FIG. 102. Lined drainage ditch for mosquito control. (Courtesy, United States Public Health Service.)

depositing of debris and the outlet side should be paved to prevent erosion of the bottom.

In loose soil, ditches may be lined with concrete, tile, or linings poured in place, rocks embedded in mortar or the ditches may be rock filled to form a "blind" ditch or "French drain." Farm tile drains are occasionally used for short distances. Precast concrete lining is now being manufactured in various "standard" sizes. The ditch lining should cover the bottom and extend up the side above the normal water line. Sod may be used for side lining above the normal water line.

Yearly or more frequent maintenance must be given to eliminate the

effects of erosion, puddles, or pools which will hold water after runoff has ceased. Removal of obstructions is constantly necessary. Loose debris should not be allowed to accumulate in any of the ditches because this reduces their capacity. Large ditches may require algaecide treatment and removal of vegetation that shelters larvae. Sub-surface drains, tiles, and blind ditches require little attention but should be regularly inspected to determine if clogging has occurred.

Digging and lining of small ditches is accomplished by hand labor. Power machinery is frequently used in the construction of large systems.

Permanent elimination of swamps, depressions and ponds that serve as breeding places, by filling with earth or other material, is the most satisfactory method of mosquito control because it eliminates breeding areas permanently and reclaims land for other uses. It is impractical for very large areas unless sufficient fill is obtainable. The initial cost is greater than for larviciding or draining but since maintenance work is not required it may ultimately be the cheapest method. Filling usually is used only if large quantities of filling material are available and the value of the reclaimed land will compensate for the expense of filling. Small areas may be filled manually with pick and shovel operations. Large fills are made with bulldozers, earth movers, and graders. The fill must be finished without low spots that might later develop into breeding areas.

The training of stream banks and trimming of the banks of ponds and lakes can be a small job that requires the work of only a few laborers or it can be an undertaking large enough for heavy construction equipment. The goal is to eliminate backwashes, depressions, and marshy places along the margins of the water bodies. The work usually consists of removing dirt in some places and filling in others. The results not only remove possible breeding places but also give a much neater appearance to the streams, ponds, or lakes. Banks of streams that are flooded during high water can be built up to hold the water away from areas beyond the normal drainage effect of the river and prevent the development of breeding areas.

Diversion of streams of water sometimes can eliminate swampy areas and the danger of mosquito breeding. Land at the base of hills frequently is swampy due to the effect of springs along the sides, which drain to the foot of the hills. The overflow from the springs can be collected into a common ditch and conducted into a free-flowing stream to get rid of the swamp and its mosquito breeding menace.

The control of *Aedes egypti* breeding places results from the elimination of water in artificial containers such as empty cans, old tires, and blocked roof gutters. The inhabitants of the community must be trained to remove or empty all containers that hold water, or else treat the water so that it is unsuitable for mosquito breeding. Water in fire buckets and other con-

tainers must be treated with a larvicide. Effective control can be maintained only by the whole-hearted cooperation of all persons in the community. On the other hand, most of the control measures are such that individual participation gives excellent results.

The use of larvicides has been one of the most widely used methods for mosquito control. There are many advantages of such a procedure, including initially cheap operation, quick results, and mobility of operation. The principal disadvantage lies in its temporary effectiveness. This means that control operations must be carried on as long as the mosquitoes exist or the presence of a susceptible population offers a disease hazard.

DDT has had great effect on the methods used for mosquito control. It has practically eliminated the use of any of the older larvacides such as paris green or crude oil.

Oil solutions should be applied at the rate of 0.05–0.2 pounds of DDT per acre. A one percent solution applied at this rate requires only 2.5 gallons per acre. To be effective the DDT must reach the larvae; therefore, the concentration of the DDT should be adjusted in accordance with the fineness of spray used. The spray must be applied as a fine mist to obtain drift over the area with the wind. A swath 50–100 feet wide is good practice with hand equipment, using a fine spray and depending on the wind. Under these conditions 2 quarts of 5 percent DDT in oil will satisfactorily cover 1 acre if a good breeze is blowing.[15] Crews can be trained to distribute the larvicide at this low rate.[21] Applications should be repeated every 7–10 days. Heavier dosage may be used to obtain an increased lasting effect but concentrations greater than 0.2 pounds per acre may kill fish and harm wild life. Water emulsions applied to rain barrels, cans, and other receptacles will give a prolonged residual effect. Oil solutions are effective against all mosquito larvae.

The solution or emulsion may be applied by a drip oiler, scattering impregnated saw-dust over the water or by spraying. Spraying with tank type sprayers is the method of choice.

Very fine dust containing 2 percent of DDT is also effective for the temporary control of Anopheles larvae. Dosage rate is 20 pounds per acre. It is usually applied with a rotary hand duster. However, one dose of 10 percent dust at the rate of 10 pounds per acre will be effective in thick vegetation for three weeks. Dust which floats on the water surface is not very efficient against Culex and Aedes since they feed below the water surface.

The overall cost of larviciding with DDT solution or emulsion is about one third that of other materials previously used.[19] When breeding acreage is extensive, airplane spraying is the most economical larvicidal method.

Fig. 103. Applications must be made in a manner to prevent indiscriminate spraying with subsequent loss of wild life. Use of DDT sprays is more effective than Paris green dust since DDT in this form is effective against all species of mosquitoes while Paris green dust does not kill Culex and Aedes larvae. DDT applied in bulk from planes is cheaper than Paris green. In populated regions and localities of heavy food or forage crop production, dispersion from an airplane may contaminate the crops and kill off beneficial insects. Both sprays and dusts may be used.

FIG. 103. Airplane spraying of larvicide for mosquito control. (Courtesy United States Public Health Service.)

One of the principal methods of mosquito control used in artificial reservoirs is the fluctuation of the water level in the reservoirs. By proper control the surface of the water can be allowed to drop at a rate fast enough to draw larvae and pupae out of the vegetation along the banks into clear water where they will die or be killed by natural enemies. Another effect of the water level manipulation is prevention of vegetation along the margin of the water body. Anopheles mosquitoes will not thrive in clear water.

Mosquito larvae and pupae are drowned rather readily if the water in which they live is agitated sufficiently. Under certain circumstances water can be held behind a dam for a period of several days and then suddenly released into the stream bed below. The turbulence of the water running through the spillway drowns any larvae or pupae that may have developed during the period the spillway was closed. The sudden flow of water also

helps to flush out any accumulation of debris collected in the stream bed below the dam. Application of this method has limited possibilities but where it can be used it is effective.

Many species of mosquitoes are particular about the places in which they breed. The clearing of vegetation from the banks of bodies of water lets in sunlight which may discourage the breeding of some species. Likewise, shading may prevent other species from breeding. Knowledge of the breeding characteristics of mosquitoes is needed to utilize this method of control. Results the reverse of those desired have been obtained in some cases.

The use of natural enemies of mosquitoes has been tried with varying success. Killifishes have been used in salt water and top minnows (*Gambusia*) have been used in fresh water. In some cases the results have been quite satisfactory. *Gambusia afinis* have been used in cisterns, and ornamental ponds or pools. They are top feeders and do not attack motionless objects. For this reason they are not effective against some species of anopheles larvae which are characteristically quiet in water. Lily pads or other vegetation may serve as protective barriers for the larvae or pupae.

Other supposed mosquito enemies, such as bats, have been tried with little success. Dragonflies are enemies of mosquitoes, the larvae of the dragonfly feeding on the larvae and pupae of mosquitoes and mature dragonflies feeding on the adult mosquitoes. They do not present a practical method for mosquito control.

Temporary elimination of adult mosquitoes in homes or outside areas can be obtained by use of DDT sprays, particularly if some pyrethrum is mixed with the DDT. Hand sprayers or the convenient aerosol "bombs" can be used for this purpose. No residual effect is produced by this treatment. Bombs are used extensively in the treatment of airplanes. Outside areas can be rendered free of mosquitoes for several hours by spraying vegetation and the outside of nearby buildings with a DDT and pyrethrum mixture. A dosage of 1 quart of 5 percent DDT per acre covered mostly with grass will provide protection for several hours. The spray should be in the form of a fine mist for this use.

In any mosquito area, whether or not disease transmission is a consideration, screening of windows and doors subsequently treated with a 5 percent solution of DDT in a suitable solvent will be found an advantage for comfort if for no other reason. Screening with an 18 by 18 mesh should be used if all species of mosquitoes are to be kept out. A mesh 16 by 16 will keep out many but it may not exclude the *Aedes egypti*. The general construction of the houses should also be checked for cracks around windows, doors, or other places where mosquitoes can enter. Screening was one of the reliable defensive measures used against malaria several years

ago. Since the anopheles mosquitoes bite at dusk, screened houses protect the inhabitants during the mosquito biting hours provided the people remain indoors.

## RAT ERADICATION

The public health importance of rats is not to be minimized. They are the host for the vectors of bubonic plague, endemic typhus fever and are the direct vector of Weil's Disease (*Leptospirosis*) spreading the disease to man by contaminating food and water with infected urine.

Great as the public health significance of rats is, because of disease directly traced to them, the secondary effects of these parasites on decreased economic well-being, destruction of food, and contamination of food, to the point where it is not suitable for human consumption, has public health importance. The economic loss due to rats is something that affects the life of everyone. The value of food destroyed and property damaged has been estimated at about $2 per rat for food destroyed and $20 per rat for property damage. Even though these estimates may vary as much as 50 or 75 percent, the resulting losses are tremendous. What is more, these are prices that are paid annually, a high penalty to pay for the presence of this guest.

Rats live under a wide variety of conditions. They eat almost anything if hungry enough. Zinsser[45] has noted that the brown rat is particularly cosmopolitan, versatile and of destructive nature. He states:

> "From the point of view of all other living creatures, the rat is an unmitigated nuisance and pest. There is nothing that can be said in its favor. It can live anywhere and eat anything. It burrows for itself when it has to, but, when it can, it takes over the habitations of other animals, such as rabbits, and kills them and their young. It climbs and it swims.
>
> It carries diseases of man and animals—plague, typhus, trichinella spiralis, rat-bite fever, infectious jaundice, possibly Trench fever, probably foot-and-mouth disease and a form of equine "influenza." Its destructiveness is almost unlimited. Lantz, of the United States Department of Agriculture, has made some approximate estimates of this, as follows (we abbreviate):—
>
> > Rats destroy cultivated grain as seeds, sprouts, or after ripening. They eat Indian corn, both during growth and in the cribs, and have been known to get away with half of the crop. A single rat can eat from forty to fifty pounds a year.
> >
> > They destroy merchandise, both stored and in transit, books, leather, harness, gloves, cloth, fruit, vegetables, peanuts, and so forth.
> >
> > The rat is the greatest enemy of poultry, killing chicks, young turkeys, ducks, pigeons; also eating enormous numbers of eggs.

Rats destroy wild birds, ducks, woodcocks, and song birds.

They attack bulbs, seeds, and young plants or flowers.

They cause enormous damage to buildings, by gnawing wood, pipes, walls, and foundations.

Hagenbeck had to kill three elephants because the rats had gnawed their feet. Rats have killed young lambs and gnawed holes in the bellies of fat swine.

They have gnawed holes in dams and started floods; they have bitten holes in mail sacks and eaten the mail; they have actually caused famines in India by wholesale crop destruction in scant years.

They have nibbled at the ears and noses of infants in their cribs; starving rats once devoured a man who entered a disused coal mine."

## Varieties of Rats

In the United States three varieties of rats of importance are prevalent. The most widely distributed is the brown rat, also known as gray, sewer, barn, wharf or Norway rat (*Rattus norvegicus*). It is identified by its large size, blunt head, short ears and the fact that its tail is shorter than the combined length of its body and head. The brown rat is a burrowing species, generally nesting in the ground but rarely at a depth exceeding 18 inches to 2 feet. It is a ferocious creature, driving out other species, and can adapt itself to nearly all conditions. If food is plentiful, it breeds 6 to 10 times a year, with an average of about 10 young per litter.

The black rat (*Rattus rattus rattus*) has disappeared from many sections of the country but persists in some isolated localities. This species generally lives in the walls of houses and between floors and ceilings. It is recognized by its slender body, pointed muzzle, sooty color and a tail which is longer than the head and body.

The third variety is the roof rat (*Rattus rattus alexandrinus*) or Alexandrian rat. It resembles the black species with the exception of its color which is more like that of the brown rat, but more yellowish on the underparts. In habits it simulates the black rat by living off the ground, frequently nesting in trees.

## Control Measures

Since the rat is a versatile creature efforts to eradicate it must be directed in several ways. There are three general types of control measures that can be taken. At times, one method may suffice, but in most cases a combination of two or all three is required to give good results. These methods are:

1. Elimination of breeding and nesting places.
2. Elimination of food supply.
3. Killing.

*Elimination of Breeding and Nesting Places*

A knowledge of the life habits of rats is necessary if best results are to be obtained in eliminating their usual haunts. The brown rat is the chief problem in this country so its control is especially important.

Since the brown rat nests in debris, rubbish, trash, or behind partitions of buildings, double floors and remote, dark corners, the elimination of these places or reconstruction to make them unsuitable for rat harborage

FIG. 104. Littered yards provide rat harborage. (Courtesy, Pathfinder News Magazine.)

is the solution. One of the best methods for ridding an area of breeding and nesting places is plain, ordinary good housekeeping. Debris and rubbish should be burned or carted off and disposed of in such a way that it will not create a nuisance.

Accumulations of lumber, piping, and other building material should be sorted over, unwanted parts disposed of, and the balance stacked and arranged neatly so that empty spaces are reduced to a minimum. The act of shifting such piles occasionally will disturb rats enough to prevent their establishment.

Elimination or prevention of nesting and breeding places in buildings

requires good housekeeping and good construction methods. Construction can be divided into two phases—remodeling or constructing the building in such a way that protected, dark spaces are rendered inaccessible to rats; and rendering entire buildings inaccessible to the rat by blocking windows, doorways and any other entrance point. This is commonly called "rat proofing" or "building the rat out." Rat proofing a building denies the rat access to food supplies. The simplest method is to eliminate all passages

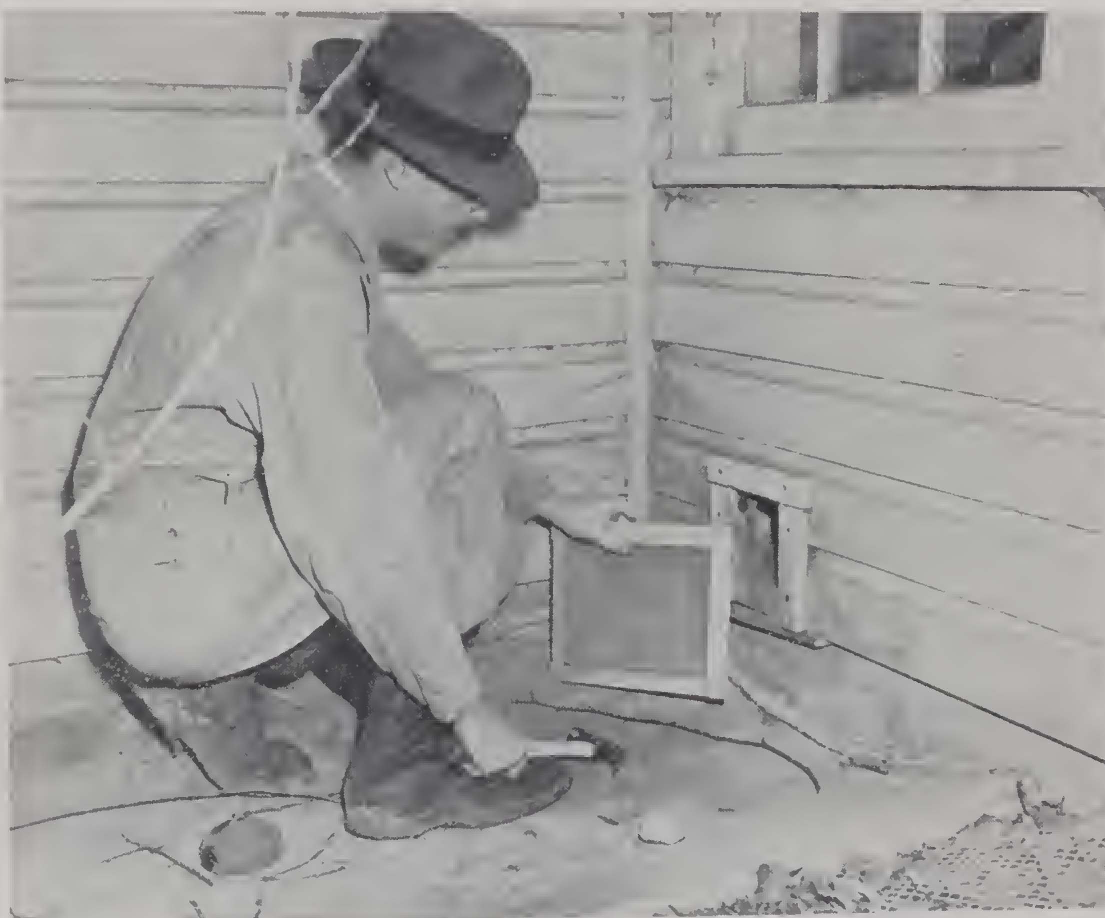

FIG. 105. "Rat proofing" an opening with wire mesh. (Courtesy, U. S. Fish and Wildlife Service.)

by which rats may enter buildings or to protect those openings which cannot be eliminated in such a way that rats cannot get through them.

The closure of external openings used by rats for ingress into buildings as a part of a murine typhus control program, has been called "vent stoppage" by the Georgia Department of Health.[4] This consists of the closure of cracks and openings in walls and foundations by replacement of missing stones, bricks or mortar; screening of ventilators, grills and sidewalk gratings; prevention of interior rat harborage by covering entrance holes in floors with sheet metal; repair of outside and cellar doors; metallic closure of openings through which pipes penetrate; placing tight metallic covers

over cellar drains; and closure of open vents in hollow walls by sheet metal or bricks.

Elimination of interior rat harborages is difficult since it frequently requires removal of walls, partitions and structural members. A building protected from the ingress of rats can be rid of the rodents by trapping and poisoning. This may require several months.

Fig. 106. Metal sheathing used for "rat proofing". (Courtesy, Georgia Department of Public Health.)

The standard form of rat proofing including elimination of inside harborage can be included in new housing construction at slight additional cost. Old buildings may be remodeled at moderate costs. Typical structures are shown in Figures 105 to 107.

### *Elimination of Food Supply*

The motivation behind rat control methods, other than those which actually kill the rat, is to make life for the rat so difficult that his time will be spent in hunting food leaving little time, energy, or opportunity for the responsibilities of family life. If living conditions are made difficult, the rat may move out to other places where he can be killed more easily. In

any event, every time the rigors of life prevent a litter of young rats or lead to a reduction in the size of the litter or in the health of the young rats, a step is taken toward fewer rats. Efforts toward control of the rat food supply should not be stopped because all sources of food cannot be eliminated.

So long as a food supply is accessible, rats will continue to be an economic and health menace. Uncovered garbage pails or scraps of food dumped in empty fields or in ditches offer sources of food supply. Careless


Fig. 107. Entrance portal for rats blocked by "vent stoppage". (Courtesy, Georgia Department of Public Health.)

storage of food supplies in unprotected buildings is one of the most important sources of sustenance. Such materials as grain or flour should be kept in masonry, rat-proof rooms, or if in bags, stored on racks high enough from the floor and far enough from walls to prevent rat access.

Proper disposal of garbage and all other waste food is essential to rodent control. A garbage dump cannot exist for many months without attracting the brown rat since the dump provides abundant food and a warm shelter. Farms and homes in immediate proximity to disposal areas always become infested by rats, making the problem of rodent control one of serious magnitude to both urban and rural districts. Residents of suburban areas without refuse collection service usually solve their garbage disposal problem by

dumping garbage upon the nearest available vacant area with the resultant development of a localized rodent infestation. It is true that rat eradication may be successful in such localized areas, but it will never permanently solve the problem as long as the dump—and food supply—is permitted to exist. The chapter on waste disposal suggests various satisfactory methods of garbage disposal. Elimination of food supplies and prevention of the creation of nesting and breeding places for rats are the chief reasons for proper garbage disposal.

### *Direct Killing of Rats*

Several methods are used in killing rats. Although one method may work satisfactorily for a period of time it is usually best to combine two or more methods to meet the particular circumstances of the situation. The methods used are:

Trapping
Poisoning
Fumigation

*Trapping* is the oldest method of rat catching. Several types of traps are used but the standards are the guillotine or snap trap and a No. 0 steel trap. Traps may be set with or without bait in the runs used by rats. When baits are used, a piece about the size of an index finger is necessary. The type should be changed every few days. Good baits are bacon, ground beef, fish, apples, and ground corn. Traps must be tended daily if good results are to be obtained. Dried bait should be replaced, traps that have been snapped without catching a prey should be reset and all traps should be checked regularly. All traps must be kept in good working order by proper oiling, straightening of trigger and of jaws as needed, and removal of any objects that may get lodged in jaws preventing free movement.

Some pointers in the use of traps include:[47]

1. Use only in rat runs.
2. Free movement of the jaws.
3. Fastening traps so that caught rats cannot drag them into a nearby hole or inaccessible place.
4. Blocking runways, after traps are set with boards, boxes or other objects so that rats will be forced to use the run in which the traps are set.
5. Use of tracking patches around area of traps to determine whether or not rats are avoiding traps.
6. Two traps at each hole or each end of a run.
7. Camouflage of traps with dust or torn paper if rats appear to be circling them.

Much argument has centered around the question of whether or not the

smell of humans frightens the rats from traps. The consensus is that with human smell all around the runs, holes, and food supply, there is no disadvantage in presence of human odor on the traps. Rats become suspicious readily so any trapping program should be put on with a generous number of traps. It is probable that rats will avoid the traps after the first few nights. In locations subject to occasional intrusion of a single or small number of rats, traps can be set regularly in the hope of catching stray animals.

Fig. 108. Poison bait inserted in permanent box located in steam tunnel used as rat runway. (Courtesy, U. S. Fish and Wildlife Service.)

*Poisoning* is the principal method used for freeing warehouses, business establishments, and other places subject to rat infestation. The procedures require careful planning and execution for successful results. As with traps, rats become frightened of baits and avoid them after several nights.

Poisoned baits are placed near runs and other places frequented by the rats. Frequently, the normal food supply can be used as the bait, provided the poisoned material can be placed about without danger of its contaminating human food. Many more baits than will be taken in any one night are more effective than a few. The more complete the kill on the first few baitings, the better the chances of ridding the premises completely.

Red squill (*Urginea maritima*), ANTU (*alphanapthyl thiourea*), 1080 (*sodium fluoroacetate*), and thallium sulfate are the poisons of choice in eradication campaigns. Zinc phosphide and arsenic trioxide are also used frequently.

Red squill may be considered the least poisonous of this group since household pets refuse to eat it and vomit if they do ingest it. ANTU is not effective against black rats and should be considered as specific for the brown (Norway) rat. It is toxic to household pets. Thallium sulfate and 1080 are soluble in water, without odor and taste and are extremely toxic to all animals, including man, with minute dosage having lethal effects.[32] They are very dangerous and should be used only by careful, expert specialists.[40] The relative toxicity of various poisons is illustrated in Table 29.

TABLE 29

*Toxicity to Man of Rodent Bait Prepared with Common Rodenticides**

| Poison | Concentration in Bait 1 part in | Ounces of Bait Lethal For 150 Pound Man |
|---|---|---|
| Arsenious acid | 33 parts | 0.12–1.22 |
| Strychnine | 320 | 0.8 |
| 1080 | 256 | 3.15 |
| Thallium sulfate | 65 | 3.2 |
| Zinc phosphide | 50 | 4.9 |
| Barium carbonate | 5 | 9.9 |
| ANTU | 20 | Many |
| Red squill | 10 | Many |

* Ward, Justus C., Amer. J. Pub. Health, **36:** 1427 (1946).

A new rodenticide, Warfarin, has been developed. It is 3-(alpha-acetonylbenzyl)4-hydroxycoumarin. It is slightly soluble in water and is effective for Norway rats and mice when placed in torpedo baits. Single baiting is not effective and several feedings are required for a lethal dose. It is toxic to humans and warm blooded animals but due to the low concentration used, 0.025 percent, there is a minimum of hazard to domestic pets. It is dangerous when used in higher doses.

Poisoned baits of various materials are satisfactory. Fresh beef, pork, horse meat, bacon, fats, lungs and tankage, fresh and canned fish and fish meal, rolled oats, cracked wheat, corn meal, bran and bread, apples, bananas, peas and pineapples, sweet or white potatoes, tomatoes, watermelon, pumpkin and cabbage, peanut butter, prepared dry dog food, seeds and cream cheese are some that are used. Bacon fat, gravy, or molasses mixed with the dry cereals serve as further lures. The poisons are usually admixed with the baits in concentrations shown in Table 29. The rodenticide is

worked into soft baits or sprinkled over hard foods. Portions of soft baits about the size of a marble are wrapped in paper to form "torpedoes" and then are placed in rat runs, along walls, in dark corners, burrows and other infested places. The type of bait must be changed, should the initial bait be uneaten. The bait must be distributed in the evening to assure freshness during the night. Uneaten bait must be promptly removed the next day. Pre-baiting is desirable in any large scale poisoning program. This consists of the use of unpoisoned material for several nights prior to the placement of the poison. As soon as a good portion of the unpoisoned baits is taken the poisoned ones can be set out. Water solutions of 1080 have been successfully utilized to kill rats on vessels and in warehouses as a replacement for fumigation.[20] Use of 1080 must be done under expert supervision. *There is no antidote for the poison 1080!* Humans have been killed through the careless or improper use of it.

The carcasses of killed rats should be collected and destroyed daily. If typhus or plague is prevalent care should be exercised to protect the persons handling the dead animals against bites of fleas that may be on the carcasses. Rats killed with 1080 must be disposed of with care. This poison is so toxic that death has resulted in hogs that have eaten rats killed with it.

*Fumigation* is a specialized method of rat eradication that has its place in certain circumstances, although with the widespread use of ANTU and the availability of 1080 this method is not used as often as it once was. Fumigation is particularly useful around warehouses with heavy infestation when a quick kill is desired. It is also used in dumps where the ready availability of food makes poisoning difficult.

Hydrocyanic acid gas is the chief fumigant used. Calcium cyanide is dusted into rat burrows or into other confined spaces. The moisture of the atmosphere combines with the powder to release hydrocyanic acid gas, which is rapidly lethal to all animals, including man. Special cellulose discs impregnated with the gas and sold under the name of "Discoids" provide a convenient method for fumigating warehouses and other large buildings or rooms that can be closed against air circulation. The discoids are shipped in sealed metal cans. When the warehouse or room has been prepared for fumigation, windows closed and sealed, all but the final exit door locked and sealed, piles of materials pulled apart, doors to closets or smaller rooms opened and warning signs put up outside the warehouse, the fumigator, equipped with gas mask, starts at the end of the room farthest from the door. As he walks back toward the door he tosses individual discoids on either side, the number depending upon the volume of the room or warehouse to be fumigated. When he reaches the door he closes it and seals it. The building is kept sealed and guarded for at least 4 hours and then is

opened again by persons wearing gas masks. After the building has been well ventilated occupancy is again permitted. Test papers are available to indicate the presence or absence of any gas.

Fumigation gives good results in a very short time. It is a dangerous process and should be allowed only under permit and by fully trained individuals.

Fig. 109. Applying cyanogas to rat burrows in a city dump. (Courtesy American Cyanamid Co.)

Methyl bromide, sulphur dioxide, and carbon monoxide have been used for fumigation. All of them are lethal to man.

## Community Organization for Rat Eradication

Before any community rat eradication program is undertaken the public should be advised of the plans and a procedure outlined for the participation of any interested groups. If poisons are going to be used at any time that fact should be explained with emphasis on the extent of the danger to humans and the precautions that should be taken to protect children and pets particularly.

Communicable disease reports will sometimes give an indication of the prevalence of rats, particularly those that may be harboring disease organisms. Otherwise, surveys must be conducted to locate the parts of town requiring eradication. The business sections and any areas where food storage or preparation is carried on are almost sure to be infested. Areas of old tenements or dilapidated buildings and neighborhoods adjacent to dumps are other susceptible locations. In general, the better the sanitation of the neighborhood, the less likelihood there is of rat infestation. Trained observers can not only detect locations of infestation but also arrive at a good estimate of the number of rats present.

A map of the infested areas should be prepared and centers of infestation noted. An outline should be prepared of the places to be attacked first and those for later treatment. Plans should also be made for the type of eradication to be done. Rat-proofing and building rats out of buildings is a slow procedure that should be planned for long range operation. Methods of municipal financing may be necessary. Coordination with the department of sanitation can frequently lead to improvement in garbage collection and disposal practices. The housing or building department should be asked to cooperate by instituting needed repairs to buildings. If proper preparations are made many groups of citizens will probably volunteer their services. They can be used to advantage with a small amount of instruction. Needless to say the person in charge of the whole program should be a trained sanitary engineer or entomologist.

A procedure for rat eradication using ANTU in ground corn meal was developed in an eastern city in 1945.[11] Some 5,574 blocks or 82 percent of the residential section was treated with the poison. The survey disclosed that an area bounded by four city blocks is sufficiently isolated in relation to rat population to be useful as a unit in eradication operations. Prebaiting was not practiced and kills of 85–95 percent were commonly obtained. Under these conditions it was found that the average city block reaches a rat population replacement of 58 percent in 1 year and complete replacement in 22 months.[32] It is apparent that yearly campaigns are required to keep the rat density below saturation level and it is questionable if of economic value. The money spent to rat proof structures is a sound investment and does not require repetition year after year. Expenditure of public funds for this work could probably be justified in some communities. In others, a revolving fund might be established so that the municipality could perform the needed rat-stoppage on private property and then bill the owner for compensation. Payment for work would keep the revolving fund solvent. Too much emphasis cannot be placed on the need for increased community interest in rat control measures. A city offers numerous haunts where rats, in close association with man, find suitable

protection for breeding. Even though some buildings may be rat-proof as to walls and foundations, carelessness on the part of occupants or owners often results in rat infestation. Methods of rat control are relatively simple. But so long as community interest lags, the rat will continue its depredation on food and other merchandise, in addition to being a health nuisance.

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Chapter XIV

# ADMINISTRATION OF SANITATION PROGRAMS

It seems unnecessary to dwell on the need in any health department for properly trained staff members competent to deal with all phases of environmental sanitation. The desirable minimum functions of a health department have been outlined by the American Public Health Association as:[4, 6]

Vital Statistics
Sanitation
Communicable Disease Control
Laboratory Service
Maternal and Child Health
Health Education

## SCOPE OF SANITATION PROGRAMS

Public health programs have grown without any carefully prearranged formula and the development of sanitation activities has been dictated to a very great extent by the pressures of existing problems and hazards rather than by long range planning. Not only does the content of a sanitation program vary but the division in the health department responsible for conducting various parts of the program is far from uniform. It is not uncommon to find responsibilities for certain sanitation activities in departments other than the public health.

There is no reason to suggest that all health departments should follow the same sanitation activity pattern, either in regard to the details included or the administrative organization. Public health programs, being official activities, must depend upon public funds for their support. This limitation dictates the scope and size of every part of the plan. In any specific community the factors included in a sanitation program reflect the desires, experiences, and needs of that group of people.

The Committee on Administrative Practice, American Public Health Association, has prepared a device for measuring the quality of a sanitation program as it is conducted in any community. The important headings of this "Sanitation Evaluation Schedule" outline by inference the factors for which good coverage is necessary. They are:[5]

Organization and Supervision of the Division
Water Supply
Milk Supply

Food Control
Domestic and Industrial Wastes
Insects and Rodents
Swimming Pools
Camp and Picnic Grounds
Housing
School Sanitation
Solid Wastes
Industrial Sanitation
Sanitation of Occupied Buildings
Nuisance Control
Community Education in Sanitation

This outline is not presented to imply that every health department or other governmental agency must have a detailed plan for each section. Rather, it is intended to show what parts of community life are of importance to the sanitation program.

The schedule was published in 1948. Since then several other activities have grown in importance. To the list can be added:

Air pollution
Accident prevention in the home
Disposal of radio active wastes

However, no list can be made comprehensive enough to cover all situations. Programs will change, dropping some activities, adding new ones and shifting attention from one to another.

Although these activities normally are functions of the health department any one of them may be conducted by some other branch of government. Under these conditions the health department should be reasonably conversant with what is being done by other departments. The importance of any item will decide to a certain extent whether it should be grouped with others and handled as a composite program or whether it should be operated independently.

In summarizing the scope of the sanitation programs the following points should be emphasized:

1. Communities will not necessarily have the same program.
2. Whatever program is accepted must be a reflection of local needs, desires and capabilities.
3. The program will be dynamic, varying with the changing needs, desires and capability of the community.
4. Where the health department does not have direct responsibility for the supervision of sanitation activities it must assist and advise the departments that are responsible.

## ORGANIZATION OF THE SANITATION SERVICE

Variations in the scope of environmental sanitation programs are reflected in the methods of organization but some general concepts are fundamental. Whatever the elements incorporated in any health department program, all of the sanitation activities should be under the same division and under the same administrator.

The administrator of the sanitation program should serve as the direct consultant to the health officer on all matters dealing with the field. Sanitation problems do not group well with any of the other major divisions of the health department. Coordination between different divisions can be obtained through an advisory council of division heads.

The chief of the sanitation division should be on a par with other division chiefs and given a free hand to administer his division. Some health officers have placed sanitation under the chief of another specialty. Usually the chief does not have the knowledge required to conduct a good program in both fields with a resultant slighting of the least known field. Obviously, the staff of a small health department may not be large enough to provide for professional personnel at the head of every division. Under these conditions the person responsible for sanitation should have professional background. Large health departments with comprehensive programs, will require further subdivision of the work which may include:

Water and Sewage
Milk and Food
Insect and Rodent Control
General Sanitation

As the specialization of the division develops, these subdivisions may be expanded to cover:

Stream Pollution
Milk and Dairy Products
Restaurants
Housing

No specific statement can be made concerning the number of sections that should be formed nor can a rule be given for dividing a section into specialties. The peculiarities of each situation must be considered. It is probable that as new sections are organized one person may supervise two or more until the programs have been developed and needed personnel acquired.

It may seem unnecessary to stress the desirability of good administrative procedures. There are frequent examples of poor administrators who insist upon making all decisions and who refuse to permit staff members to assume the responsibilities of their job. The sanitation administrator should

present to the health officer the complete program and section heads should formulate programs for the specialties.

## Personnel

One of the greatest advances made in public health in recent years has been the establishment of professional requirements for responsible positions in health departments. One of the objects of every administrator should be the improvement of the professional standard of his staff by careful selection of qualified individuals and by furnishing opportunity for those persons to receive further training. Selection of personnel should be made on the basis of merit, including education, experience and personal qualifications.

### *Specialties Required*

Very large sanitation divisions require specialists according to the scope of the program undertaken. The Committee on Professional Education of the American Public Health Association has recommended educational qualifications for public health (sanitary) engineers.[7] These call for a basic college training with graduation in a sanitary engineering course or in that option of the civil or chemical engineering curriculum. Following this basic preparation graduate work should be undertaken in engineering or public health. Graduate work may be taken after several years of health department experience. In these recommendations educational qualifications are augmented with experience as follows:

Grade I— No experience required.

Grade II— At least 1 year of suitable experience in sanitary engineering under competent supervision.

Grade III—At least 2 years of suitable experience in sanitary engineering work in a grade comparable to Grade II, of which at least 1 year must be in public health. (Total 3 years sanitary engineering, 1 year in public health.)

Grade IV—At least 2 years of sanitary engineering experience in a grade comparable to Grade III of which at least 2 years must be in a responsible position in public health. (Total 5 years sanitary engineering, 3 years in public health.)

Grade V— At least 5 years of sanitary engineering experience in a grade comparable to Grade IV, of which at least 5 years must be in a responsible position in public health. (Total 10 years sanitary engineering, 5 years in public health.)

The recommendations also specify that the educational training for all grades should satisfy the academic requirements for admission to examination for license to practice engineering in the state.

A second category of professional personnel is the numerous sanitation workers who are not engineers but who qualify as professional persons. These usually fall in the group called "sanitarian." They are persons with college training in such specialties as animal husbandry, dairy industry, entomology, veterinary medicine, food processing, and other specialties related to public health. They are a part of the professional staff. Definite health department qualifications have not been established but experience with a public health agency and formal graduate work in public health or the application of the specialty to health problems should be considered as basic training. Grades of experience based on length and type of service similar to those established for engineers should be utilized as qualifying individuals for progressively important positions.

A second kind of "sanitarian" is being employed on health department staffs. This individual has a college degree but does not have specialization in any specific field. He has, rather, a training of limited extent in many of the sciences of importance to public health. Many persons so trained are performing in an excellent manner in health departments, indicating a permanent need for this type of training. To be fully qualified for professional standing the individual should have further graduate work in public health.

Another group of employees used in the sanitation field is composed of persons lacking formal college training. Some individuals may have completed part of a college course but many have not gone beyond high school. Health department experience indicates that there is a place for these employees in performing routine restaurant inspections, insect and rodent control eradication programs and other work that does not require a high degree of technical knowledge. Initial careful selection and inservice training with supervised experience should qualify the individual for important subordinate positions. Only unusual persons should be considered as suitable for positions requiring professional status.

### *Selection of Administrators*

The health officer must decide in which specialty the sanitation administrator should quality. Local circumstances must be considered but there are some general criteria:

1. The person selected must have administrative and professional ability.
2. He should have recognized professional standing in the community and among other professions.
3. He should be in a position to call upon the support of other professional groups for advice and active support.

Since engineering factors are involved in the solution of many sanitation problems an engineer is the logical choice to head this division. State license

laws require that many activities dealing with water supply, sewage disposal, control of air pollution, and stream pollution abatement be conducted by registered engineers. The training of engineers makes them particularly competent for administration problems.

Chiefs of sections in the sanitation division should be selected for administrative competence and for ability in their particular field.

*Personnel Requirements*

The number of persons required for sanitation services has been estimated by several administrators. The most comprehensive study was made by Emerson.[3] In this study it is estimated that an engineer is needed in each local health unit of 50,000 or more persons. Small health departments may not have budgets that will permit the employment of an engineer. Under these circumstances adequate supervision would be provided by engineering services from a higher level of government such as country, district or state. The total sanitation personnel (engineers, other professional personnel and sub-professional persons) average about 1 per 25,000 population as a minimum. Programs that include more than basic coverage require a larger staff. Objection has been made to these figures because of the method of estimating. Gross population apparently does not provide a suitable method for computing personnel needs. The scope of programs, effect of geographical and climatological factors and other characteristics of the community have an important bearing on the number of persons needed.

Board[2] has studied the distribution of food establishments in communities of various sizes. The results indicate that population bases are not suitable for determining staff size to cover the food sanitation program. Similar studies would probably show the same lack of correlation between population and other features of a sanitation program. Using data from the U. S. Census Reports, 1940, Board found that in 92 cities with a population of 100,000 or more the number of all food establishments varied from 55.5 to 5.2 per 1,000 population. When only eating and drinking establishments were considered the spread in the same 92 cities with populations over 100,000 was 22.0 to 1.7 per 1,000 population.

Another method of estimating personnel needs has also been used. It is based upon a time analysis of the specific activities to be performed such as inspections, conferences and study of problems, and the frequency of performance. With this method an inventory is made of the different activities that are to be covered and an administrative decision is made as to the frequency of participation. On the basis of this information the number of man hours necessary can be computed and translated into men working on a yearly basis. An example will serve to illustrate the method:

Poole computed the number of engineers required for district offices

in Indiana by first estimating the work load. A few items in the computation showed:

| Facility | Units × "K" | Man Days Per Year |
|---|---|---|
| Tourist camps | 221 × 3/5 | 133 |
| Schools | 467 × 3/4 | 350 |
| Swimming Pools | 19 × 3/4 | 15 |
| County Fair Grounds | 22 × 1 | 22 |
| Promotion of Ordinances | 41 × 1 | 41 |

"K"—Numerator is number of inspections or participations per year; denominator is number made in 1 day. Thus 3/5 indicates the operation will be performed thrice yearly for each unit and 5 units can be done in 1 day.

In all, 25 different activities gave a total man days (field work) of 1679. Assuming that 75 percent of engineering time was spent in the field this gives a total man day requirement of 2240. On the basis of 250 work days per year per man the estimated man power was 9 persons.

A third method is being studied by the Michigan Association of Sanitarians.[8] A record of the time spent in performing various functions by several sanitarians in Michigan was made using a special record form. Provision was made for including the time of travel required and certain other activities were shown by using proper code numbers. Analysis of the data collected should furnish valuable aid for administrators who must compute manpower needs for immediate or future requirements.

Usually the problem will not be to determine whether 15 or 18 men are needed but to try to get at least one man for work that very obviously needs to be done. Should it be necessary to analyze manpower needs to substantiate requests for funds, the best method at present would be one similar to that used by Poole.

## PROGRAM OF THE SANITATION DIVISION

The health officer must determine on the basis of local need the general program. The sanitation division head should then develop the details of his own plan. The interests of other official agencies must be considered in preparing the program. Departments of municipal government responsible for refuse collection, operation of water and sewage plants, control of buildings and the school system have an interest in local sanitation programs. At all levels the engineer must coordinate the activities of his department with other agencies that may have some influence upon his work.

The value of civic cooperation should not be neglected. Efforts should be made to keep the community aware of the sanitation program by bringing representative citizens into active consultation with the division. This can be accomplished to a certain extent by participation in technical groups

and societies. The citizen supports the program by taxes. It is as important that he understand why money is spent to see that the barnyard of a dairy farm is graded and drained as it is that he knows why funds are used to assure that every infant is immunized against diphtheria and whooping cough. There is as much preventive public health in the sanitation part of the health department program as there is in the program of any other major division.

## Preventive Sanitation

Given adequate personnel, a good sanitation program should prevent complaints since frequent inspections and surveys reduce nuisance and health hazards. Many complaints are based upon neighborhood feuds and do not constitute a health hazard but must be accepted as a factor in the sanitation program.

Complaints must be answered promptly. Usually a health nuisance is not the fault of the complainant and it is the responsibility of the health department to abate it promptly. Furthermore, prompt attention to complaints impresses the complainant with the efficiency of the personnel and helps to establish good public relations. Complaints also lead to the discovery of conditions unknown to the department and provide an opportunity for better coverage.

## Records

A record of the work performed and the results obtained is necessary for the measurement of effectiveness. Accurate records should be kept to measure progress and show the results of work undertaken. They can be used as a basis for developing new methods and for keeping the community informed of the activities undertaken. Should court action be necessary good records can prove the charges made.

At least two types of records are needed. One should record the day to day individual activities of each person, giving details of time, place, person seen, conditions found, and other pertinent data. The second should consist of a condensation of the individual reports and serve as a permanent running record of events.

The check type of investigation sheet has proved its worth in many instances. It is convenient and time saving. Another type of field record that has extensive value in analysis is the "mark-sensing" card. Records are made on machine record cards by filling in small blocks with a special graphite pencil. The cards are then run through a punching machine and holes are punched in the cards in accordance with the marked record. If several programs are conducted under the sanitation division it is possible that two or more "sensing" cards will be necessary to permit coverage of

all programs. The convenience of this type of record lies in the fact that information can be punched on cards directly from the field notations. The cards are then suitable for machine sorting. Examples of mark sensing cards developed by the Seattle, Washington, Health Department are shown in Fig. 110.

## Criteria for Adequate Supervision

There is no clear cut agreement among sanitation administrators about the frequency with which various activities of the division program should be performed. Any standards, goals, or criteria that may be set must be modified in the light of conditions existing in any community. During

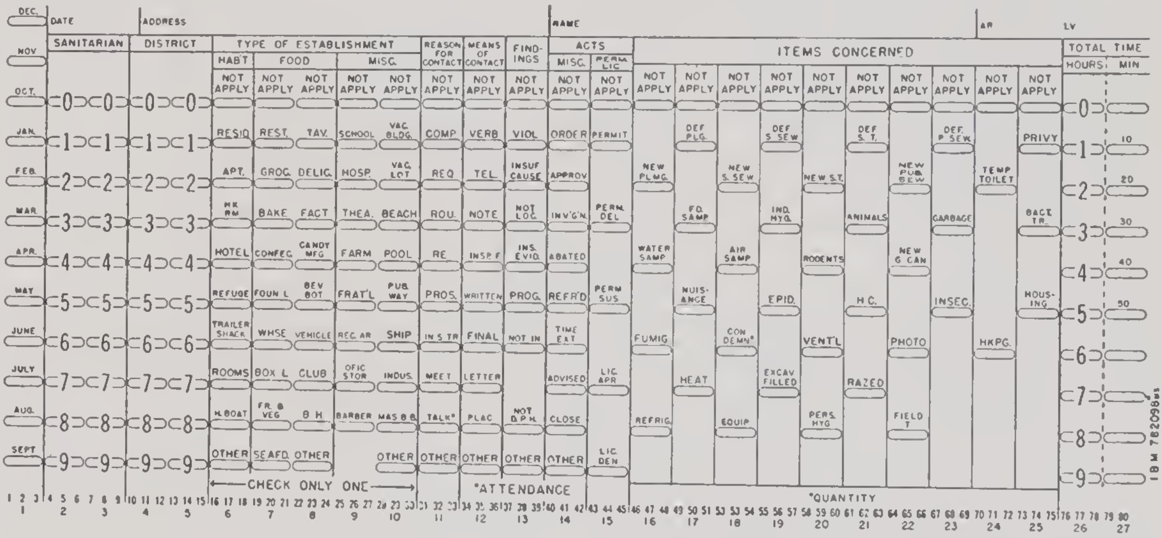


Fig. 110. Use of mark sensing card in reporting sanitation activities. (Courtesy, Seattle Department of Health.)

periods of a program development it should be expected that the quality of coverage will not be as good as would be expected in a well established program. The quality of personnel will have an effect, also, on the results obtained. The following suggestions are given as an indication of how common practice is likely to vary.

## Suggested Activity Accomplishments

Water supplies

All systems surveyed within past 5 years.

Number of bacteriological samples at least equal to those required by the U. S. Public Health Service Drinking Water Standards.

Percentage of population served by approved municipal water supply

in cities of population over 2500. . . . . . . . . . . . . . . . . 98.0*

in cities of population 200 to 2500 . . . . . . . . . . . . . . . 85.0*

* After figures in "Grading Standards for A.P.H.A. Evaluation Schedule", Committee on Administrative Practice, Amer. Pub. Health Assoc., March, 1950.

| | |
|---|---|
| **Milk supply** | |
| Inspections per year per retail raw dairy farm | 5 to 8 |
| Bacteriological samples per year per retail raw dairy farm | 6 to 12 |
| Inspections per year per plant producer dairy farm | 0.5 to 2 |
| Bacteriological samples per year per plant producer dairy farm | 4 to 8 |
| Inspections per year of pasteurizing plants | 12 to 24 |
| Bacteriological samples per year per pasteurizing plant | 12 to 35 |
| **Food Control** | |
| Percentage of eating and drinking establishments visited per year | 75 to 100 |
| Percentage of restaurants and lunch counters with approved facilities | 95* |
| Percentage of restaurants and lunch counters with approved methods | 95* |
| Percentage of slaughter houses surveyed each year | 75 to 100 |
| **Sewage Disposal** | |
| Percentage of plans for community systems examined by health department | 75 to 95 |
| Percentage of population connected to approved systems | |
| in cities of more than 2500 population | 95* |
| in cities of 500 to 2500 population | 80* |
| **Swimming pools** | |
| Bacteriological examinations per month per pool | 1 to 4 |
| Percentage of pools meeting bacteriological standards | 90 to 95 |
| Percentage of pools meeting standards of construction and operation | 85 to 95 |
| **Camps and picnic grounds** | |
| Inspections per month of operation of camp | 0.4 to 1 |
| Percentage of camps with satisfactory water supply | 85 to 100 |
| excreta disposal | 85 to 100 |
| refuse disposal | 80 to 95 |
| Percentage of picnic grounds with satisfactory water supply | 85 to 95 |
| excreta disposal | 85 to 95 |
| **Schools** | |
| Inspections per month | 0.5 to 1 |
| Percentage of enrollment in schools with approved water supply | 90 to 100 |
| excreta disposal | 85 to 95 |

| | |
|---|---|
| Percentage of pupils with adequate lighting | 80 to 90 |
| ventilation | 80 to 90 |
| Percentage of pupils in schools with approved cafeteria facilities | 100* |
| methods | 100* |
| Complaints | |
| Percentage of complaints justified | 80 to 95 |
| justified complaints abated | 90 to 95 |

The higher criteria will apply for the better developed departments where programs have been conducted for several years. Good personnel should be able to show a marked steady improvement in the levels reached in any part of the sanitation program. Recognition should also be given to the fact that less frequent inspections are required of those establishments found to have good facilities and trained, conscientious staff and supervision. Frequency of performance of any activity will also depend upon the size of the sanitation staff—frequently less often than that required for satisfactory performance.

## Financing Program

Most sanitation divisions are financed by public funds. The amount provided depends upon local needs and acceptance of the sanitation program. The report, "Local Health Units for the Nation"[3] considered 30 cents per capita the minimum yearly budget that could be expected to provide the basic sanitation program. That estimate was made in 1942. It is probable that with the decrease in the value of the dollar that has occurred since then at least 60 cents per capita per year would be required to furnish a minimum program. The amount that will be made available by any community depends upon the clarity with which the community sees the need for the expenditures. It is the responsibility of the health department to convince the citizens of its community that such funds will bring the desired results.

The major portion of any sanitation budget will continue to come from general tax sources. Increased federal aid may mean that more state money will be made available for all health department activities. This of course is still general tax money. An interesting development has been found successful in some communities. Largely at the suggestion of various commercial groups, special sanitation programs have been set up to supervise the activities of those groups. An agreement was made between the health department and the commercial interests on the size of the budget that would be needed to finance the program. Special license fees were then levied in amounts to assure the total of the estimated budget. Legislation has permitted the health department to retain the funds collected from the

licenses for financing the specific program. Several cities on the west coast have developed a relationship of this nature. The meat sanitation program of the Seattle health department is supported by fees from special licenses.[1]

## Legal Enforcement

Any health department that has a large number of court actions is admitting its inability to meet the responsibilities of the department without using the arm of the law. Resort to court action is an admission of failure to sell the program to the community. There is a strong regrettable tendency on the part of many sanitation division personnel to use the ordinance book as the reason for obedience to certain rules and regulations.

Good public acceptance of the sanitation program should make court action unnecessary. Every health department staff member should be advised that summons will be issued only as a last resort. Every other possible way for settling differences of opinion must be tried. Education is the best way to prevent legal actions. The health department staff member must learn how to obtain compliance without using the law.

Many court actions can be prevented by holding hearings of an informal nature. During these hearings the complaining staff member can have a chance to present his case. The offending citizen can have an opportunity to explain his actions. In such a hearing it is possible to present to the offending person a reasonable explanation of the department's viewpoint.

Persuasion, explanation, education and compromise have their limitations. There are instances where nothing but court action obtains the required results. Before initiating court action it is well to review the case with the legal representative of the department or city to assure that proper care has been taken in its preparation.

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